How Abiotic Processes, Biotic Processes, And Their Interactions Sustain Habitat Characteristics And Functions In River Channels And Their Floodplains: An Investigation Of The Response Of A Gravel−Bed Reach Of The Merced River To Restoration

prepared by Dunne, Thomas

submitted to Science Program 2004

compiled 2005−01−06 16:21:30 PST

Project

This proposal is for the Science Program 2004 solicitation as prepared by Dunne, Thomas .

The submission deadline is 2005−01−06 17:00:00 PST (approximately 38 minutes from now).

Proposal updates will be disabled immediately after the deadline. All forms, including the signature form, must be completed, compiled and acknowledged in order to be eligible for consideration and review. Allow at least one hour for Science Program staff to verify and file signature pages after they are received.

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Proposal Title	***How Abiotic Processes, Biotic Processes, and Their Interactions Sustain Habitat Characteristics and Functions in River Channels and their Floodplains: An Investigation of the Response of a Gravel−Bed Reach of the Merced River to Restoration***	
Institutions	University of California, Santa Barbara University of British Columbia California Department of Water Resources	*List each institution involved, one per line.*
Proposal Document		*You have already uploaded a proposal document. View it to verify that it appears as you expect. You may replace it by uploading another document*
Project Duration	*36 months*	

Is the start date a determining factor to the successful outcome of the proposed effort?
X No.
− Yes. Anticipated start date of this effort:

Select all of the following study topics which apply to this proposal.
X life cycle models and population biology of key species
X environmental influences on key species and ecosystems
− relative stresses on key fish species
− direct and indirect effects of diversions on at−risk species
− processes controlling Delta water quality
− implications of future change on regional hydrology, water operations, and environmental processes
− water management models for prediction, optimization, and strategic assessments
− assessment and monitoring
X salmonid−related projects
− Delta smelt−related projects

Select as many keywords as necessary to describe this proposal (minimum of 3).
X adaptive management
− aquatic plants
X benthic invertebrates
− biological indicators
− birds
− neotropical migratory birds
− shorebirds
− upland birds
− wading birds
− waterfowl
− climate
− climate change
− precipitation
− sea level rise
− snowmelt
− contaminants / toxicants / pollutants

− contaminants and toxicity of unknown origin
− emerging contaminants
− mercury
− nutrients and oxygen depleting substances
− organic carbon and disinfection byproduct precursors
− persistent organic contaminants
− pesticides
− salinity
X sediment and turbidity
− selenium
− trace metals
− ***database management***
− ***economics***
X engineering
− civil
X environmental
X hydraulic
− ***environmental education***
− ***environmental impact analysis***
− ***environmental laws and regulations***
− ***environmental risk assessment***
X fish biology
− bass and other centarchids
− delta smelt
− longfin smelt
X other species
X salmon and steelhead
− splittail
− striped bass
− sturgeon
− ***fish management and facilities***
− hatcheries
− ladders and passage
− screens
− ***forestry***
− ***genetics***
− ***geochemistry***
− ***geographic information systems (GIS)***
− ***geology***
X geomorphology
− ***groundwater***
X habitat
X benthos
− channels and sloughs
− flooded islands
X floodplains and bypasses
− oceanic
− reservoirs
X riparian
X rivers and streams
− shallow water
− upland habitat
− vernal pools
X water column
− wetlands, freshwater
− wetlands, seasonal
− wetlands, tidal
− ***human health***
X hydrodynamics
X hydrology
− ***insects***
− ***invasive species / non−native species / exotic species***
− ***land use management, planning, and zoning***
− ***limnology***
− ***mammals***

− large
− small
− ***microbiology / bacteriology***
X modeling
− conceptual
X quantitative
− ***monitoring***
− ***natural resource management***
− ***performance measures***
− ***phytoplankton***
X plants
− ***primary productivity***
− ***reptiles***
X restoration ecology
X riparian ecology
X sediment
− ***soil science***
− ***statistics***
− ***subsidence***
− ***trophic dynamics and food webs***
− ***water operations***
− barriers
− diversions / pumps / intakes / exports
− gates
− levees
− reservoirs
− ***water quality management***
− ag runoff
− mine waste assessment and remediation
− remediation
− temperature
− urban runoff
− water quality assessment and monitoring
− ***water resource management***
− ***water supply***
− demand
− environmental water account
− water level
− water storage
− ***watershed management***
− ***weed science***
− ***wildlife***
− ecology
− management
− wildlife−friendly agriculture
− ***zooplankton***
− ***administrative***

Indicate whether your project area is local, regional, or system−wide. If it is local, provide a central ZIP Code. If it is regional, provide the central ZIP Code and choose the counties affected. If it is system−wide, describe the area using information such as water bodies, river miles, and road intersections.	
X local	ZIP Code: ***95369***
− regional	ZIP Code: counties:

− system−wide	

Does your project fall on or adjacent to tribal lands?
No.

(Refer to California Indian reservations to locate tribal lands.)
If it does, list the tribal lands.

Has a proposal for this effort or a similar effort ever been submitted to CALFED for funding or to any other public agency for funding?
No.

If yes, complete the table below.

Status	Proposal Title	Funding Source	Amount	Comments

Has the lead scientist or principal investigator of this effort ever submitted a proposal to CALFED for funding or to any other public agency for funding?
No.

If yes, provide the name of the project, when it was submitted, and to which agency and funding mechanism if was submitted. Also describe the outcome and any other pertinent details describing the proposal's current status.

T. Dunne and M.B.Singer received a grant from the CALFED Science Program entitled “Large−scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology” The grant extends from 2002 to 2005, and is funded at $390,252. To date we have produced the following publications

1.Singer, M.B. and T. Dunne; Identifying eroding and depositional reaches of valley by analysis of suspended sediment transport in the Sacramento River, California. Water Resources Research, 37(12):3371−3382. 2001 2.Singer, M.B. and T. Dunne; Modeling decadal bed−material sediment flux based on stochastic hydrology. Water Resources Research, 40, W03302, doi: 10.1029/2003WR002723. 2004 3.Singer, M.B. and T. Dunne; An empirical−stochastic, event−based program for simulating inflow from a tributary network: Framework and application to the Sacramento River basin, California. Water Resources Research, 40, W07506, doi:10.1029/2003WR002725. 2004 4. Singer, M.B. and R.A. Aalto; Event−based sedimentation and scour in flood bypasses: A case study from the 1964 flood in the Sacramento Valley, California. Submitted to journal. 5. Singer, M.B.; Influence of major dams on hydrographs through a river network. Submitted to journal 6. Constantine, C.R., T. Dunne, M.B. Singer. Submitted to journal. 7 .Singer, M.B. and T. Dunne; Modeling the decadal influence of river rehabilitation scenarios on flow and sediment transport in large, lowland river basins. In Preparation 8. Dunne, T. River Restoration as a Challenge to Hydrological Science, Invited Langbein Lecture at Nice, France and San Francisco Meetings, American Geophysical Union. Powerpoint presentation posted on the AGU website.(www.agau.org).

We have also presented talks with published abstracts at 9 conferences in California (two at the CALFED Science Conference), nationally and internationally. Other papers are in preparation. We have also participated in many workshops and informal meetings with agency and university scientists working on CALFED projects.

The project continues to document rates of overbank transport of fine sediment into the floodplains, flood basins, and flood bypasses of the Sacramento River Valley. A coring program to measure rates of sedimentation with the Lead−210 isotope has resulted in more than 100 cores being collected and the laboratory work is currently underway. We have also begun to calculate the overbank transport and sequestration of mercury on the sedimen. We anticipate publication of at least five more papers in the international literaure.

All applicants must identify all sources of funding other than the funds requested through this solicitation to support the effort outlined in their proposal. Applicants must include the status of these commitments (tentative, approved, received), the source, and any cost−sharing requirements. Successful proposals that demonstrate multiple sources of funding must have the commitment of the non−Science Program PSP related funding within 30 days of notification of approval of Science Program PSP funds. If an applicant fails to secure the non−Science Program PSP funds identified in the proposal, and as a result has insufficient funds to complete the project, CBDA retains the option to amend or terminate the award. The California Bay−Delta Authority reserves the right to audit grantees.

Status	Proposal Title	Funding Source	Period Of Commitment	Requirements And Comments

Are you specifically seeking non−federal cost−share funds for this proposal?
No.

In addition to the general funds available, are you targeting additional funds set aside specifically for collaborative proposals?
No.

List people you feel are qualified to act as scientific reviewers for this proposal and are not associated with CALFED.

Full Name	Organization	Telephone	E−Mail	Expertise
Prof. W. E. Dietrich	*Earth and Planetary Science, University of California Berkeley*	*510−642−2633*	*bill@eps.berkeley.edu*	
Prof. M.E. Power	*Integrative Biology, University of California Berkeley*	*510−643−7776*	*mepower@socrates.berkeley.edu*	
Dr. R.E. Bilby	*NW Fisheries Science Center, NOAA Fisheriesy, Seattle, WA*	*206−860−3334*	*robert.bilby@noaa.gov*	
Dr. Tim J. Beechie	*NW Fisheries Science Center, NOAA Fisheries, Seattle, WA*	*206−860−3409*	*tim.beechie@noaa.gov*	

Executive Summary

Provide a brief but complete summary description of the proposed project; its geographic location; project objective; approach to implement the proposal; hypotheses being tested; expected outcomes; and relationship to Science Program priorities. The Executive Summary should be a concise, informative, stand−alone description of the proposed project. *(This information will be made public on our website shortly after the closing date of this PSP.)*

We propose to use restored reaches of the Merced River to generate knowledge for the design of river restoration throughout the CALFED domain and elsewhere. This proposal is designed to quantify the linkages between biotic and abiotic processes, and the degree to which complex ecosystem structures can arise from initially simple restored environments and can continue to support an abundance of native species without continual intervention. We will initially focus on the 1.4 mile−long Robinson Reach of the Merced River (Figure 1), within a 4.5 mile−long reach rehabilitated in the Merced River Salmon Habitat Enhancement Project, managed by the California Department of Fish and Game (CDFG), the California Department of Water Resources (CDWR), the CALFED Bay Delta Program, the U.S Fish and Wildlife Service (USFWS), the U.S. Bureau of Reclamation (USBR), and the Robinson Cattle Company, which owns the land. The research has been designed by a team of specialists, who are challenged by the need to collaborate across their disciplines in generating scientific understanding for the purposes of river restoration, and whose expertise includes the main four components of the restored ecosystem: • channel and floodplain hydrology, hydraulics, sedimentation, geomorphology, project design and construction (Dunne and Faulkenberry) • invertebrate food organisms (Lenihan) • salmonid and other fish populations (Healey and Kendall) • riparian and floodplain plants (Davis)

The proposal involves intensive field surveys of hydraulics, sedimentation processes, channel change, habitat conditions, invertebrate and fish communities and theor interactions. It will also involve field experiments, and construction of mathematical models to explore, link, and generalize the results. It will focus on the response of the ecosystem to variables that can realistically be manipulated in river restoration and for which better quantitative biological and physical information is needed in planning and design. Although the initial stages of the project will be conducted in the Robinson reach and immediately upstream and downstream, we hope to gradually expand our results in later years through comparative studies in other rivers restored and un−restored rivers in the region. The overarching questions to be addressed are: • How do abiotic and biotic processes in a restored, simplified channel−floodplain system interact to develop the conditions that favor a set of native and endangered species of plants and animals? • How can knowledge of these relationships be translated into successful river management? • Can the restoration of these physical processes create self−sustaining habitats that support an abundance of native species with only limited interventions by management agencies? Each component of the study re−states these general questions in terms appropriate for specific scientific investigation, and each component is tightly linked to the others with joint data collection exercises, data analyses and modeling efforts (e.g. concerning hydrodynamics, geomorphology, and invertebrate distributions; or hydrodynamics, geomorphology and fish use of the channel; or floodplain plant community assembly related to floodplain microtopography and sedimentation).

The scientific investigation is designed to provide information that is directly useful for restoration design and other river management. Some of the experiments planned will explore ways of accelerating the development of ecosystem structure that might be incorporated into future designs for river and floodplain restoration. The opportunity for experiments at this initially simple site, and for comparisons with more complex neighboring sites that have received other treatments or that remain un−restored will be pursued in cooperation with agencies as knowledge accumulates from this project.

The questions relate to the PSP study topics inquiring (i) about processes and their relationships to water management and key species, and (ii) about improving tools for performance assessment and for evaluating implications of future changes. The questions also address one of the fundamental concepts underpinning the CALFED Program, namely that restoration of physical processes is the best way to restore habitat for desirable populations of organisms [CALFED Strategic Plan, 2000].

Give additional comments, information, etc. here.

The project is a collaboration between personnel from the University of California Santa Barbara, the University of British Columbia, and the California Department of Water Resources.

Applicant

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All information on this page is to be provided for the agency or institution to whom funds for this proposal would be awarded.

Applicant Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Applicant Institution Type	***public institution of higher education***	

Institution Contact

Please provide information for the primary person responsible for oversight of grant operation, management, and reporting requirements.

Salutation	***Dr.***
First Name	***Thomas***
Last Name	***Dunne***
Street Address	***Bren Hall 3510 University of California Santa Barbara***
City	***Santa Barbara***
State Or Province	***CA***
ZIP Code Or Mailing Code	***93106−5131***
Telephone	***805−893−7557*** *Include area code.*
E−Mail	***tdunne@bren.ucsb.edu***

Additional information regarding prior applications submitted to CALFED by the applicant organization or agency and/or funds received from CALFED programs by applicant organization or agency may be required.

Personnel

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Instructions

Applicants must provide brief biographical sketches, titles, affiliations, and descriptions of roles, relevant to this effort, of the principal and supporting project participants by completing a Personnel Form. This includes the use of any consultants, subcontractors and/or vendors; provide information on this form for all such people.

Information provided on this form will automatically support subsequent forms to be completed as part of the Science PSP submission process. Please be mindful of what information you enter and how it may be represented in the Task and Budget forms.

Information regarding anticipated subcontractor services must be provided regardless if the specific service provider has been selected or not. If the specific subcontractor has not been identified or selected, please list TBD (to be determined) in the Full Name field and the anticipated service type in the Title field (example: Hydrology Expert).

Please provide this information before continuing to those forms.

Dunne, Thomas

*This person is the **Lead Investigator**. Contact information for this person is required.*

Full Name	***Dunne, Thomas***	example: Wright, Jeffrey R., PhD.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	1. Research on Hydrodynamics and Fluvial Geomorphology 2. Coordination of the interdisciplinary study	
Qualifications		*You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*
Mailing Address	***School of Environmental, 3510 Bren Hall, University of California Santa Barbara***	
City	***Santa Barbara***	
State	***CA***	
ZIP	***93106−5131***	
Business Phone	***805−893−7557***	
Mobile Phone	***805−705−4333***	
E−Mail	***tdunne@bren.ucsb.edu***	

Describe other staff below. If you run out of spaces, submit your updates and return to this form.

Davis, Frank

Full Name	***Davis, Frank***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*

Title	***Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Research on floodplain and riparian vegetation	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. <u>Review the file</u> to verify that appears correctly.*

Healey, Michael A.

Full Name	***Healey, Michael A.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Research on fish ecology	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. <u>Review the file</u> to verify that appears correctly.*

Kendall, Bruce

Full Name	***Kendall, Bruce***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Associate Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Research on modeleing fish population dynamics and behavior	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. <u>Review the file</u> to verify that appears correctly.*

Lenihan, Hunter S.

Full Name	***Lenihan, Hunter S.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Assistant Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Research on invertebrate ecology and population dynamics	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. <u>Review the file</u> to verify that*

		appears correctly.

Faulkenberry, Kevin

Full Name	***Faulkenberry, Kevin***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Senior Engineer, Department of Water Resources***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Plannning of how the field and modeling studies fit into the goal of using the Robinson reach in an adaptive management strategy for learning how to improve river restoration practices, both on the Merced River and on other rivers in the region. Coordination of measurements made for this project with the ongoing monitoring program. Coordination with agencies to explore the opportunities for manipulative experiments in the reach. Coordination with agencies to explore opportunities for extending the study with comapraisons outside of the Robinson reach, where the agencies have an interest in other forms of restoration. Ensuring that the project fits the goals and concerns of management agencies, regulatory agencies, and the landowner.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Legleiter, Carl

Full Name	***Legleiter, Carl***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Ph.D. student funded by an American Society for Engineering Education National Defense Science and Engineering Graduate Fellow, and a National Science Foundation Graduate Research Fellow***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Responsible for empirical and modeling studies of the flow field, bed−material sediment characterization, and bed morphology. He will conduct the aerial surveys of the reach with optical and lidar sensors. He is independently supported by fellowships from the National Science Foundation and the American Society of Civil Engineers.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Wydzga, Aleksandra

Full Name	***Wydzga, Aleksandra***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*

Title	***Graduate Student Researcher***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Field studies of sediment intrusion into the channel bed and its effect on spawning habitat quality	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Postdoctoral Researcher #1

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Postdoctoral Researcher #1***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Field and modeling studies of hydrodynamics and channel geomorphology change	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Undergraduate Students

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Undergraduate Students***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assistance with field surveys of hydrodynamics, sediment, invertebrates, and fish	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Computer Programmer

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Computer Programmer***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Writing computer programs to facilitate mathematical modeling and data analysis	

Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Postdoctoral Researcher #2

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Postdoctoral Researcher #2***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Field surveys and experimentation on invertebrate communities and their interactions with physical habitat conditions and predators.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Postdoctoral Researcher #3

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Postdoctoral Researcher #3***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Field research on fish demography and habitat use.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Postdoctoral Researcher #4

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Postdoctoral Researcher #4***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Mathematical modeling of fish demography, energetics, and behavior.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Senior Development Engineer

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Senior Development Engineer***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Installation, development, and maintenace of fish monitoring and sediment monitoring equipment	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Consulting Technician

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Consulting Technician***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Installation and calibration of fish counting equipment	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Postdoctoral Researcher #5

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Postdoctoral Researcher #5***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Field and modeling research on colonization of floodplain environments by plant communites.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Graduate Student Researcher

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa***	*This list comes from the project form.*

	Barbara	
Title	***Graduate Student Researcher***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Field surveys of plant communities on floodplain and data analysis	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Computer Technologist

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Santa Barbara***	*This list comes from the project form.*
Title	***Computer Technologist***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assistance with database management and GIS analysis of floodplain plant communities.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Conflict Of Interest

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Instructions

To help Science Program staff manage potential conflicts of interest in the review and selection process, we need some information about who will directly benefit if your proposal is funded. We need to know of individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded;
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.

Applicant	University of California, Santa Barbara
Submittor	Dunne, Thomas
Primary Staff	Dunne, Thomas
Primary Staff	Davis, Frank
Primary Staff	Healey, Michael A.
Primary Staff	Kendall, Bruce
Primary Staff	Lenihan, Hunter S.
Primary Staff	Faulkenberry, Kevin
Primary Staff	Legleiter, Carl
Secondary Staff	Wydzga, Aleksandra
Secondary Staff	*Postdoctoral Researcher #1
Secondary Staff	*Undergraduate Students
Secondary Staff	*Computer Programmer
Secondary Staff	*Postdoctoral Researcher #2
Secondary Staff	*Postdoctoral Researcher #3
Secondary Staff	*Postdoctoral Researcher #4
Secondary Staff	*Senior Development Engineer
Secondary Staff	*Consulting Technician
Secondary Staff	*Postdoctoral Researcher #5
Secondary Staff	*Graduate Student Researcher
Secondary Staff	*Computer Technologist

Are there other persons not listed above who helped with proposal development?
No.

If there are, provide below the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

Tasks

This proposal is for the Science Program 2004 solicitation as prepared by Dunne, Thomas .

The submission deadline is 2005−01−06 17:00:00 PST (approximately 38 minutes from now).

Proposal updates will be disabled immediately after the deadline. All forms, including the signature form, must be completed, compiled and acknowledged in order to be eligible for consideration and review. Allow at least one hour for Science Program staff to verify and file signature pages after they are received.

Instructions

Utilize this Task Table to delineate the tasks identified in your project description. Each task and subtask must have a number, title, brief description of the task (detailed information should be provided in the project description), timeline, list of personnel or subcontractors providing services on each specific task, and list of anticipated deliverables (where appropriate). When creating subtasks, information must be provided in a way that avoids duel presentation of supporting tasks within the overall task (i.e. avoid double counting). Information provided in the Task Table will be used to support the Budget Form. Ensuring information regarding deliverables, personnel and costs associated with subtasks are only provided once is imperative for purposes of avoiding double counting of efforts within the Budget Form.

For proposals involving multiple institutions (including subcontractors), the table must clearly state which institutions are performing which tasks and subtasks.

Task ID	Task Name	Start Month	End Month	Personnel Involved	Description	Deliverables
1	*Coordination of Project*	*1*	*36*	*Dunne, Thomas*	Ensure that various team members are measuring and analyzing the data that are critical to the overall goal of the project. Coordinate measurement programs, experiments, and data analysis.	Scientific publications; summary reports to agency; organization of workshops with agency personnel and other researchers as the need arises.
2	*Hydrodynamics and Geomorphology: measurements.*	*1*	*36*	*Dunne, Thomas Faulkenberry, Kevin Legleiter, Carl Wydzga, Aleksandra *Postdoctoral Researcher #1 *Undergraduate Students *Computer Programmer*	Definition of the hydrodynamics, sediment transport, sedimentation, and channel change of the Merced River study sites under a range of flows and sediment supply.	Scientific articles and reports to funding agency. Digital databases of physical habitat measurements.
3	*Hydrodynamics and Geomorphology: models*	*1*	*36*	*Dunne, Thomas Faulkenberry, Kevin *Postdoctoral Researcher #1 *Computer Programmer*	Mathematical modeling of flow field and channel migration. Application of models to restoration concerns.	Scientific articles.
4	*Invertebrate communities*	*1*	*36*	*Lenihan, Hunter S. *Undergraduate Students *Postdoctoral Researcher #2*	Surveys and experiments on factors controlling the distribution and demography of macroinvertebrate organisms. Modeling of the interactions observed. Application of models to restoration concerns.	Scientific articles and reports to funding agency. Digital databases of invertebrate organism measurements.
5	*Fish communities*	*1*	*36*	*Healey, Michael A. *Undergraduate Students *Postdoctoral Researcher #3*	Counting of fish entering and leaving the study reach; tracking of fish within the reach; observations of spawning behavior and other habitat use; measurement of food consumption.	Scientific articles and reports to funding agency. Digital databases of fish numbers, distribution, and condition.

				Senior Development Engineer *Consulting Technician		
6	***Fish models***	***1***	***36***	***Healey, Michael A. Kendall, Bruce *Postdoctoral Researcher #4***	Development of models of fish population dynamics, energetics, and migration. Application of models to restoration concerns.	Scientific articles and reports to funding agency.
7	***Floodplain vegetation***	***1***	***36***	***Davis, Frank *Undergraduate Students *Postdoctoral Researcher #5 *Graduate Student Researcher *Computer Technologist***	Vegetation surveys and experiments. Interpretation of results through statistical and simulation models. Application of models to restoration concerns.	Scientific articles and reports to funding agency. Digital databases of measurements on fish numbers, distribution, and condition.

Budget

This proposal is for the Science Program 2004 solicitation as prepared by Dunne, Thomas .

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Instructions

All applicants must complete a budget for each task and subtask. The Budget Form uses data entered in the Task Form, thus tasks should be entered before starting this form. Failure to complete a Budget Form for each task and/or subtask will result in removal of the application from consideration for funding.

CBDA retains the right to request additional information pertaining to the items, rates, and justification of the information presented in the Budget Form(s).

Supporting details on how costs were derived for each line item must be included in the justification section for each item. The cost detail for each item should include the individual cost calculations associated with each line item to provide the basis for determining the total amount for each budget category.

Following are guidelines for completing the justification section of this form:

Labor (Salary &Wages)

Ensure each employee and associated classification is correctly identified for each task and subtask. This information will automatically be provided once the Staff Form has been completed. Provide estimated hours and hourly rate of compensation for each position proposed in the project.

Employee Benefits

Benefits, calculated as a percentage of salaries, are contributions made by the applicant for sick leave, retirement, insurance, etc. Provide the overall benefit rate and specify benefits included in this rate for each employee classification proposed in the project.

Travel

Travel includes the cost of transportation, subsistence, and other associated costs incurred by personnel during the term of the project. Provide purpose and estimated costs for all travel. Reoccurring travel costs for a particular task or subtask may be combined into one entry. The number of trips and cost for each occurrence must be clearly represented in the justification section for reoccurring travel items of this nature.

Any reimbursement for necessary travel and per diem shall be at rates specified by the California Department of Personnel Administration for similar employees (www.dpa.ca.gov/jobinfo/statetravel.shtm).

Equipment

Equipment is classified as any item of $5,000 or more and has an expected life of three years or more. Equipment purchased in whole or in part with these grant funds must be itemized. List each piece of equipment and provide a brief description and justification for each.

Supplies

Provide a basic description and cost for expendable research supplies. Costs associated with GIS services, air photos, reports, etc. must be listed separately and have a clear justification associated with each entry. Postage, copying, phone, fax and other basic operational costs associated with each task and subtask may be combined unless the cost associated with one particular service is unusually excessive.

Subcontractor Services

Subcontractor services (Professional and Consultant services) include the total costs for any services needed by the applicant to complete the project tasks. Ensure the correct organization is entered in the Personnel Form so that it appropriately appears on the Budget Form. The applicant must provide all associated costs of all subcontractors (i.e. outside service providers) when completing this form. Applicants must be able to demonstrate that all subcontractors were selected according to an applicant's institutional requirements for the selection of subcontractors (competitive selection or sole source justification).

CBDA retains the right to request that a subcontractor provide cost estimates in writing prior to distribution of grant funds.

CBDA retains the right to request consultant, subcontractor, and/or outside service provider cost estimates in writing prior to distribution of grant funds.

Indirect Costs (Overhead)

Indirect costs are overhead expenses incurred by the applicant organization as a result of the project but are not easily identifiable with a specific project. The indirect cost rate consists of a reasonable percentage of all costs to run the agency or organization while completing the project. List the cost and items associated with indirect costs. (These items may include general office expenses such as rent, office equipment, administrative staff, operational costs, etc. Generally these items are represented by the applicant through a predetermined percentage or surcharge separate from other specific costs of items necessary to complete a specific task or subtask.)

If indirect cost rates are different for State and Federal funds, please identify each rate and the specific items included in the calculation for that rate.

Task 1, Coordination Of Project: Labor	Justification	Amount
Dunne, Thomas	*15% Summer month yearly*	*8437*
Task 1, Coordination Of Project: Benefits	**Justification**	**Amount**
Dunne, Thomas	*at 12.7%*	*1072*
Task 1, Coordination Of Project: Travel Expenses	**Justification**	**Amount**
Task 1, Coordination Of Project: Supplies And Expendables	**Justification**	**Amount**
Office/Presentation Supplies	*Telephone tolls, photocopy, fax, project mailing costs for collaborative efforts*	*15*
Task 1, Coordination Of Project: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 1, Coordination Of Project: Equipment	**Justification**	**Amount**
Task 1, Coordination Of Project: Other Direct	**Justification**	**Amount**
Task 1, Coordination Of Project: Indirect (Overhead)	**Justification**	**Amount**
CBDA Negotiated Rate Of 25% Of Modified Total Direct Costs	*On base of $9524*	*2381*
	Task 1 Total	$11,905
Task 2, Hydrodynamics And Geomorphology: Measurements.: Labor	**Justification**	**Amount**
Dunne, Thomas	*35% Summer month yearly*	*19688*
Faulkenberry, Kevin		
Legleiter, Carl		
Wydzga, Aleksandra	*49% academic level of effort, 2 summer months at 100%, all three years*	*69878*
***Postdoctoral Researcher #1**	*50% time yearly, three years*	*66908*
***Undergraduate Students**	*1000 hours yearly, three years*	*30000*
***Computer Programmer**	*7.5% time for all three years*	*15458*
Task 2, Hydrodynamics And Geomorphology: Measurements.: Benefits	**Justification**	**Amount**
Dunne, Thomas	*at 12.7%*	*2501*
Faulkenberry, Kevin		
Legleiter, Carl		
Wydzga, Aleksandra	*1.3% academic, 3.0% summer, plus Graduate Student Health Insurance and Tuition/Fees*	*34338*
***Postdoctoral Researcher #1**	*at 17%*	*11374*
***Undergraduate Students**		
***Computer Programmer**	*at 22%*	*3401*
Task 2, Hydrodynamics And Geomorphology: Measurements.: Travel Expenses	**Justification**	**Amount**
Task 2, Hydrodynamics And Geomorphology: Measurements.: Supplies And Expendables	**Justification**	**Amount**
Other	*Aerial surveys of channel with digital optical sensors*	*10000*

Other	*Servicing and insurance for boat &truck (cost shared with tasks 4, 5, &7)*	*3600*
Other	*Field supplies and tools − $5600; MATLAB software license $429*	*6029*
Other	*Preparation and publishing of reports*	*2667*
Other	*Materials for constructing microtopography template −$2000; 2 Pressure tranducers @ $1100 ea: Global Water Instrumentation; 2 data loggers @ $2997 ea*	*10194*
Other	*Helley−Smith bedload sampler and bag−$1735; Marsh McBirney current meter (Flo−mate 2000) w/top−setting wading rod −$3995; Modified standpipe for gravel sampling−$750*	*6480*
Other	*US P−72 Suspended load point sampler−$3995; Sediment balance (1kg)−$250; Range finder−$810; Digital camera &underwater case−$1000*	*6055*
Other	*Fifty Electronic scour monitors−$2500;Passive integrated transponder evaluation kit−$595; 100 each 32 mm &23 mm read−write glass transponders−$783*	*3878*
Other	*Computer desktop/monitor/software shared with task 5 (image processing, stereo mapping, photo processing)−$3594; Two computers shared with tasks 3/4/5 for downloading field equipment−$1215*	*4809*

Task 2, Hydrodynamics And Geomorphology: Measurements.: Subcontractors	**Justification**	**Amount**
	No subcontractor was assigned to this task.	

Task 2, Hydrodynamics And Geomorphology: Measurements.: Equipment	**Justification**	**Amount**
Boat With Outboard Engine And Trailer	*Shared with tasks 4 &5*	*1553*
Pickup Truck	*Shared with tasks 4, 5, &7*	*9000*
Acoustic Doppler Profiler With Boat Mount (Nortek)	*Shared with task 4*	*10100*
Total Station	*All task 2*	*9720*
Geophones For Acoustic Monitoring System With Data Logger	*Task 2 − for recording bed mobility*	*5000*

Task 2, Hydrodynamics And Geomorphology: Measurements.: Other Direct	**Justification**	**Amount**
Long−Distance Phone, Photocopying, Fax, And Project Mailing Costs	*To allow collaboration with other project personnel*	*530*

Task 2, Hydrodynamics And Geomorphology: Measurements.: Indirect (Overhead)	**Justification**	**Amount**
CBDA Negotiated Rate Of 25% Of Modified Total Direct Costs	*On base of $275,628*	*68907*
	Task 2 Total	$412,068

Task 3, Hydrodynamics And Geomorphology: Models: Labor	**Justification**	**Amount**
Dunne, Thomas	*50% Summer month yearly*	*28125*
Faulkenberry, Kevin		
***Postdoctoral Researcher #1**	*50% for three years*	*66908*
***Computer Programmer**	*42.5% for three years*	*87593*

Task 3, Hydrodynamics And Geomorphology: Models: Benefits	**Justification**	**Amount**
Dunne, Thomas	*at 12.7%*	*3572*
Faulkenberry, Kevin		
***Postdoctoral Researcher #1**	*at 17%*	*11374*
***Computer Programmer**	*at 22%*	*19270*

Task 3, Hydrodynamics And Geomorphology: Models: Travel Expenses	Justification	Amount
Other	*6 field trips per year to Merced, three people, Mileage @ $300/trip, shared with task 5*	*2810*
Other	*Rent for communal apartment in field area (shared with task 5)*	*28095*
Other	*Per diem expenses for food, 180 person−days @ $50/day per person (shared with task 5)*	*14047*
Conferences	*Three trips to a professional meeting in the US (shared with task 5)*	*6275*
Other	*Four in−state trips to CalFed Science meeting (shared with task 5)*	*3122*

Task 3, Hydrodynamics And Geomorphology: Models: Supplies And Expendables	Justification	Amount
Other	*MATLAB software license (shared with tasks 2 &6)*	*429*
Other	*Preparation and publishing reports*	*2667*
Other	*Two computers for downloading field equipment (shared with tasks 2, 4, &5)*	*1215*

Task 3, Hydrodynamics And Geomorphology: Models: Subcontractors	Justification	Amount
No subcontractor was assigned to this task.		

Task 3, Hydrodynamics And Geomorphology: Models: Equipment	Justification	Amount

Task 3, Hydrodynamics And Geomorphology: Models: Other Direct	Justification	Amount
Long−Distance Phone, Photocopying, Fax, And Project Mailing Costs	*To allow collaboration with other project personnel*	*426*

Task 3, Hydrodynamics And Geomorphology: Models: Indirect (Overhead)	Justification	Amount
CBDA Negotiated Rate Of 25% Of Modified Total Direct Costs	*On base of $275,928*	*68982*
	Task 3 Total	$344,910

Task 4, Invertebrate Communities: Labor	Justification	Amount
Lenihan, Hunter S.	*1 summer month yearly*	*23141*
*Undergraduate Students	*700 hours yearly*	*21000*
*Postdoctoral Researcher #2	*100% all three years*	*133815*
Task 4, Invertebrate Communities: Benefits	**Justification**	**Amount**
Lenihan, Hunter S.	*at 12.7%*	*2939*
*Undergraduate Students	*at 3%*	*630*
*Postdoctoral Researcher #2	*at 17%*	*22749*
Task 4, Invertebrate Communities: Travel Expenses	**Justification**	**Amount**
Other	*Four field trips per year to Merced, 3 people, Mileage @ $300/trip; lodging at $90 each; per diem @ $75/day per person*	*20041*
Conferences	*1 trip to a professional meeting in the US yearly*	*1249*
Other	*Two in−state trips to CalFed Science meeting*	*3122*

Task 4, Invertebrate Communities: Supplies And Expendables	Justification	Amount
Other	*Laboratory supplies, including isotope chemicals &analysis*	*11500*
Other	*Isotope analysis − 100/year @ $50*	*15000*
Other	*Field sampling gear*	*12000*
Other	*Field mesocosms and fish enclosure/exclosures*	*13000*
Other	*Laptop computer*	*4500*
Other	*Servicing and insurance for boat &truck (cost shared with tasks 2, 5, &7)*	*1200*
Other	*Liquid Nitrogen*	*750*
Other	*Two computers shared with tasks 3/4/5 for downloading field equipment−$1215 (shared with tasks 2, 3, &5)*	*1215*
Other	*Two turbidity, pH, DO, conductivity sensor, YSI−556 w/PC cable (shared with task 5)*	*779*

Task 4, Invertebrate Communities: Subcontractors	Justification	Amount
No subcontractor was assigned to this task.		

Task 4, Invertebrate Communities: Equipment	Justification	Amount
Boat With Outboard Engine And Trailer	*Shared with tasks 2 &5*	*1554*
Pickup Truck	*Shared with tasks 2, 5, &7*	*3000*
Acoustic Doppler Profiler With Boat Mount (Nortek)	*Shared with task 2*	*10100*

Task 4, Invertebrate Communities: Other Direct	Justification	Amount
Long−Distance Phone, Photocopying, Fax, And Project Mailing Costs	*To allow collaboration with other project personnel*	*1584*

Task 4, Invertebrate Communities: Indirect (Overhead)	Justification	Amount
CBDA Negotiated Rate Of 25% Of Modified Total Direct Costs	*On base of $290,213*	*72553*
	Task 4 Total	$377,421

Task 5, Fish Communities: Labor	Justification	Amount
Healey, Michael A.	*One month consulting services yearly (shared with task 6)*	*20505*
*Undergraduate Students	*1000 hours yearly*	*30000*
*Postdoctoral Researcher #3	*100%, three years*	*133815*
*Senior Development Engineer	*100%, three years*	*162000*
*Consulting Technician	*For set−up of fish monitoring equipment, 2 weeks yearly in years 1 &2*	*20200*
Task 5, Fish Communities: Benefits	**Justification**	**Amount**
Healey, Michael A.	*n/a − under Consulting Services*	*0*
*Undergraduate Students	*at 3%*	*900*
*Postdoctoral Researcher #3	*at 17%*	*22749*
*Senior Development Engineer	*at 22%*	*35640*
*Consulting Technician	*n/a − under Consulting Services*	*0*
Task 5, Fish Communities: Travel Expenses	**Justification**	**Amount**
Other	*6 field trips per year to Merced, 3 people, Mileage @ $300/trip − shared with task 2*	*2809*

Other	*Rent for communal apartment in field area − shared with task 2*	*28094*
Other	*Per diem expenses for food; 180 person days @ $50/day − shared with task 2*	*14047*
Conferences	*Three trips to professional meetings in the US yearly − shared with task 2*	*3090*
Other	*Four in−state trips to CalFed Science Meeting − shared with task 2*	*3121*
Air/Train	*Air travel for consultant from Vancouver to Sacramento*	*4995*
Other	*Lodging and food for consultant − 30 days @ $150/day yearly*	*14047*
Other	*Car rental for consultant−30 days @ $50/day yearly*	*4682*
Task 5, Fish Communities: Supplies And Expendables	**Justification**	**Amount**
Other	*Servicing and insurance for boat &truck (cost shared with tasks 2, 4, &7)*	*6000*
Other	*Field supplies and tools*	*8400*
Other	*Stereo microscope−$1467; Ohaus Balances−small (*	*4362*
Other	*Computer desktop/monitor/software shared with task 2 (image processing, stereo mapping, photo processing)−$3595; Two computers shared with tasks 2/3/4 for downloading field equipment−$1215*	*4810*
Other	*Nets and traps for fish*	*6000*
Other	*Two turbidity, pH, DO, conductivity sensor, YSI−556 w/PC cable (shared with task 4)*	*779*
Other	*Two Floy tagging guns and 1000 tags*	*2500*
Task 5, Fish Communities: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 5, Fish Communities: Equipment	**Justification**	**Amount**
Boat With Outboard Engine And Trailer	*Shared with tasks 2 &4*	*4660*
Pickup Truck	*Shared with tasks 2, 4, &7*	*15000*
2 Lotek SRX400A W	*6−element fish telemetry package*	*15728*
PIT System For Fish	*including 500 tags*	*5000*
100 Coded Radio Tags For Fish	*Task 5*	*20000*
Two BioSonics DT−X Ps	*Fish counting equipment*	*130000*
Underwater Video Camera And Recording/Anslysis System	*Deep Sea Power &Light Company*	*9262*
Task 5, Fish Communities: Other Direct	**Justification**	**Amount**
Long−Distance Phone, Photocopying, Fax, And Project Mailing Costs	*To allow collaboration with other project personnel*	*1181*
Construction Services For Fish Monitoring	*Task 5*	*30000*
Task 5, Fish Communities: Indirect (Overhead)	**Justification**	**Amount**
CBDA Negotiated Rate Of 25% Of Modified Total Direct Costs	*On base of $564,726*	*141181*
	Task 5 Total	$905,557
Task 6, Fish Models: Labor	**Justification**	**Amount**

Healey, Michael A.	***One month consulting services yearly (shared with task 5)***	***10099***
Kendall, Bruce	***One summer month yearly***	***23339***
***Postdoctoral Researcher #4**	***100%, three years***	***133815***
Task 6, Fish Models: Benefits	**Justification**	**Amount**
Healey, Michael A.	***n/a − under Consulting Services***	***0***
Kendall, Bruce	***at 12.7%***	***2965***
***Postdoctoral Researcher #4**	***at 17%***	***22749***
Task 6, Fish Models: Travel Expenses	**Justification**	**Amount**
Other	***4 field trips per year to Merced, 2 people − mileage @ $300/trip; Lodging @ $90 each; 5 days per diem @ $75/day per person***	***15359***
Conferences	***1 trip to professional conference in US yearly***	***1249***
Other	***2 in−state trips to CalFed Science meetings yearly***	***3122***
Task 6, Fish Models: Supplies And Expendables	**Justification**	**Amount**
Other	***Preparation and publishing reports***	***4000***
Other	***MATLAB software license (shared with tasks 2 &3)***	***442***
Other	***Preparation &publishing reports***	***2666***
Task 6, Fish Models: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 6, Fish Models: Equipment	**Justification**	**Amount**
Task 6, Fish Models: Other Direct	**Justification**	**Amount**
Long−Distance Phone, Photocopying, Fax, And Project Mailing Costs	***To allow collaboration with other project personnel***	***1282***
Task 6, Fish Models: Indirect (Overhead)	**Justification**	**Amount**
CBDA Negotiated Rate Of 25% Of Modified Total Direct Costs	***On base of $221,087***	***55273***
	Task 6 Total	$276,360
Task 7, Floodplain Vegetation: Labor	**Justification**	**Amount**
Davis, Frank	***1 summer month yearly***	***44118***
***Undergraduate Students**	***700 hours yearly***	***21000***
***Postdoctoral Researcher #5**	***100% for three years***	***133815***
***Graduate Student Researcher**	***49% academic and 100% for two summer months yearly***	***65705***
***Computer Technologist**	***1 month yearly***	***21629***
Task 7, Floodplain Vegetation: Benefits	**Justification**	**Amount**
Davis, Frank	***at 12.7%***	***5603***
***Undergraduate Students**	***at 3%***	***630***
***Postdoctoral Researcher #5**	***at 17%***	***22749***
***Graduate Student Researcher**	***1.3% academic, 3% summer, plus Graduate Student Health Insurance and Tuition/Fees***	***33360***
***Computer Technologist**	***at 22%***	***4759***
Task 7, Floodplain Vegetation: Travel Expenses	**Justification**	**Amount**
Other	***4 field trips per year to Merced, 3 people − mileage @ $300/trip; Lodging @ $90 each; 5 days per diem @ $75/day per person***	***21164***
Conferences	***1 trip to a professional meeting in the US yearly***	***1249***
	2 in−state trips to CalFed Science meetings yearly	***3122***

Other		
Task 7, Floodplain Vegetation: Supplies And Expendables	**Justification**	**Amount**
Other	***Laboratory supplies***	***9500***
Other	***Preparation and publishing reports***	***4000***
Other	***Computer***	***2500***
Other	***Pressure chamber for xylem potential measurements***	***3500***
Other	***Servicing and insurance for boat &truck (cost shared with tasks 2, 4, &5)***	***1200***
Task 7, Floodplain Vegetation: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 7, Floodplain Vegetation: Equipment	**Justification**	**Amount**
Pickup Truck	***Shared with tasks 2, 4, &5***	***3000***
Task 7, Floodplain Vegetation: Other Direct	**Justification**	**Amount**
Long−Distance Phone, Photocopying, Fax, And Project Mailing Costs	***To allow collaboration with other project personnel***	***1267***
Surveys Of Channel And Floodplain With Lidar Sensor	***Surveys−task 7***	***10000***
Soil Texture And Nutrient Analyses	***Task 7***	***3000***
Task 7, Floodplain Vegetation: Indirect (Overhead)	**Justification**	**Amount**
CBDA Negotiated Rate Of 25% Of Modified Total Direct Costs	***On base of $381,710***	***95429***
	Task 7 Total	$512,299
	Grand Total	$2,840,520

− The indirect costs may change by more than 10% if federal funds are awarded for this proposal.

What is the total of non−federal funds requested? ***2840520***

HOW ABIOTIC PROCESSES, BIOTIC PROCESSES, AND THEIR INTERACTIONS SUSTAIN HABITAT CHARACTERISTICS AND FUNCTIONS IN RIVER CHANNELS AND THEIR FLOODPLAINS: AN INVESTIGATION OF HOW A REACH OF THE MERCED RIVER RESPONDS TO RESTORATION

PROJECT PURPOSE

The over-arching scientific question of the project is:

- *How do abiotic and biotic processes in a restored, simplified channel-floodplain system interact to develop the conditions that favor a set of native and endangered species of plants and animals?*

Each of the four study components described below will re-state this question in the form appropriate to the particular object of study, but it is intended that the results will be assembled into multi-faceted answers to the following policy-relevant questions:

- *How can knowledge of these relationships be translated into successful river management?*
- *Can the restoration of these physical processes create self-sustaining habitats that support an abundance of native species with only limited interventions by management agencies?*

The questions relate to the PSP study topics inquiring (i) about processes and their relationships to water management and key species, and (ii) about improving tools for performance assessment and for evaluating implications of future changes. The questions also address one of the fundamental concepts underpinning the CALFED Program, namely that restoration of physical processes is the best way to restore habitat for populations of native organisms [CALFED Strategic Plan, 2000].

In order to address these questions, at the nexus of hydrodynamics, geomorphology, biology, and management, the six PIs, from several disciplines including channel engineering and project management, began discussions of how to conduct a *process-based* study of the biological effects of channel engineering and consequent physical processes. The study was planned during visits to the Merced River, taking advantage of a database already assembled by river management agencies. The challenge was to plan research directly relevant to the needs of river restoration managers in designing and assessing future projects in the region.

The proposal is a collaboration between PIs at three institutions. Four of them are at the University of California Santa Barbara. Healey is a Professor at the University of British Columbia, Canada, and will be paid as a consultant to UCSB though he will work as a PI. Principal Investigator Faulkenberry works for the California Department of Water Resources, and will be paid by that agency. All finances for the project will be managed by UCSB. The need for 5 pages extra pages per major component of the effort in this collaboration was confirmed by staff at the agency Help line for this submittal (06/01/05 to K. Scheidemen, UCSB).

The PIs propose to investigate how a widespread form of river restoration (restructuring and rescaling of a channel and floodplain to diminished flows) influences

physical processes, and how the altered physical conditions affect macroinvertebrates, fish, and floodplain plants. The main focus is on how river restoration affects the abundance and distribution of salmonid and non-salmonid fishes at critical life stages, initially at the scale of a single project reach (~1.4 miles of the Merced River), although some limited comparisons will be made with neighboring channel reaches and with other CALFED-restored rivers as we develop collaborations with the managers of these projects. Connections between the channel and floodplain, also considered to be critical to sustainable river restoration [CALFED, 2000], is an important part of the proposed study, to be investigated at the process level. We intend to develop fundamental ecological and geomorphological knowledge that is relevant to restoration by taking advantage of certain favorable characteristics of the field site for conducting experiments and comparing it with other channels in the region.

We intend to take advantage of the newness and simplicity of the Robinson reach to design experiments on ways of adding structural complexity to the reach. The initial simplicity of the reach provides a great opportunity to accumulate results quickly by means of such experiments.

PROJECT DESCRIPTION

Dominant Conceptual Model of River Restoration in CALFED Projects

Understanding how conservation and restoration interventions influence biological resources in California rivers is a key objective of state and federal resource agencies. The prevailing paradigm for river restoration within central California, and specifically within the California Bay-Delta Restoration Program, is that establishment of a naturalized, self-regulating, alluvial river channel, connected to its floodplain, will produce a cascade of benefits through the re-establishment of spawning and rearing conditions, initially for salmon, and coincidentally for the successful development of a number of other native aquatic, riparian, and floodplain organisms. Based upon decades of study by the community of aquatic ecologists and river restoration professionals in California, summarized in both the scientific literature and in various resource assessments and baseline survey reports [e.g. Stillwater Sciences, 2001, 2002; Trush et al., 2000], it has been proposed that a self-regulating alluvial river, supporting a diversity and abundance of native species including salmonids, has the following components:

- Unconstrained banks that allow the river channel to migrate laterally to create, maintain, and rejuvenate pools (rearing habitat), point bars (shallow margin rearing habitat), riffles (spawning habitat), and floodplains (riparian and terrestrial habitat).
- A gravel-bottomed river that is mobilized and redeposited frequently enough to destroy, create, and maintain sufficient spawning and rearing habitat.
- Temporal patterns of flow conditions, sediment loads, water quality, and water temperatures that favor the long-term survival of numerous native species whose life cycles are adjusted to these variations.

This conceptual framework constitutes the richest and most thoroughly elaborated paradigm available to river restoration professionals for re-establishing the linkages between what was formerly a dynamic physical environment and the biogeochemical and biological processes that yielded the biodiversity and productivity which are now diminished. However, it is essentially a qualitative model, conceptualized through comparative studies and informal observations in several rivers. We are not aware of any published quantitative study of the process linkages underlying this broad conceptual model, which hinders planning, design, and assessment of projects. Now that some examples of the paradigm have been implemented, it is possible to use them:

- to refine and elaborate some of the original design concepts,
- to answer questions about the desired biological responses by expanding studies of fish, invertebrates, and plants,
- to quantify the strengths of the hypothesized linkages between abiotic and biotic processes as the river systems evolve after restoration,
- to quantify how the reach-scale changes operate within the larger river systems in which they are nested.

Summary of the Proposed Study

We propose to use restored reaches of the Merced River to generate knowledge for the design of river restoration throughout the CALFED domain and elsewhere. This proposal is designed to quantify the linkages between biotic and abiotic processes, and the degree to which complex ecosystem structures can arise from initially simple restored environments and can continue to support an abundance of native species without continual intervention. We will initially focus on the 1.4 mile-long Robinson Reach of the Merced River (Figure 1), within a 4.5 mile-long reach rehabilitated in the Merced River Salmon Habitat Enhancement Project, managed by the California Department of Fish and Game (CDFG), the California Department of Water Resources (CDWR), the CALFED Bay Delta Program, the U.S Fish and Wildlife Service (USFWS), the U.S. Bureau of Reclamation (USBR), and the Robinson Cattle Company, which owns the land.

The research has been designed by a team of specialists, who are challenged by the need to collaborate across their disciplines in generating scientific understanding for the purposes of river restoration, and whose expertise includes the main four components of the restored ecosystem:

- channel and floodplain hydrology, hydraulics, sedimentation, geomorphology, project design and construction (Dunne and Faulkenberry)
- invertebrate food organisms (Lenihan)
- salmonid and other fish populations (Healey and Kendall)
- riparian and floodplain plants (Davis)

The six co-investigators designed the research, after extensive interaction with river management agencies, because of their interest in defining long-discussed linkages between desirable biological responses and those physical characteristics of river channels and fluvial processes that are manipulated in river restoration projects. They also are challenged by the need to provide scientific results in forms that are directly useful for restoration and other forms of river management. Thus, the strength of the project lies in its structural integrity, in which physical and biological scientists will utilize a strongly coupled set of approaches and techniques to answer some questions of general significance for river restoration. It is intended that there will be explicit, quantitative linkage between the results of the four study components. Individuals will use one another's results to create predictive models collaboratively, and the emphasis will be on providing models that are useful in restoration projects in the region and elsewhere.

The proposal involves intensive field measurements and construction of mathematical models to explore and generalize the results. It will focus on the response of the ecosystem to variables that can realistically be manipulated in river restoration and for which better quantitative biological and physical information is needed in planning and design. Although the initial stages of the project will be conducted in the Robinson reach and immediately upstream and downstream, we hope to gradually expand our results in later years through comparative studies in other rivers restored and un-restored rivers in the region. The research will be conducted in close consultation with the California Department of Water Resources and the California Department of Fish and Game, the agencies responsible for management and post-project monitoring of the restoration, to ensure that the research is compatible with restoration goals and constraints, takes advantage of the existing restoration design, management, and monitoring activities, and is compatible with all regulations governing biological resources and water quality.

The integrated research plan is designed around the concept illustrated in Figure 2, namely that disturbance regimes (driven by both episodic and chronic --- 'pulse' and 'press' --- processes) in the channel-floodplain system interact with the population dynamics of diverse groups of organisms to create ecosystem structure and function. In the newly restored system, physical and biological complexity is low because of the need for a manageable design, construction costs, and logistics, and the agreement of stakeholders on straightforward conceptual models that often involve compromises between preferred goals. However, over time, it is the expectation of the designers that the simplified ecosystem will be re-arranged by the re-established natural processes, and will develop spatial and temporal structure and greater overall complexity. Because the channel-floodplain ecosystem constitutes a complex adaptive system, it may evolve towards a range of future states, depending on the magnitude, frequency, and sequencing of events that are currently unpredictable. The multi-faceted research program would measure, explain, and explore the predictability of such emerging complexity to facilitate design of other restoration projects.

Description of the Site

The Robinson reach is part of the Merced River Salmon Habitat Enhancement Project, which aims to restore sustainable salmonid habitat and channel/floodplain function under the modern reservoir-dominated flow regime, along 4.5 miles of the Merced River (RM 40.0 - 44.5) near the town of Snelling, CA. After extensive degradation over the preceding 150 years, approximately 1.5 million tons of sediment was moved with machinery in 2001 to re-grade and re-surface the channel and floodplain with selected sediment. Alterations have occurred at the scales of the site and river reach, and other changes are planned, such as gravel augmentation and the rehabilitation of neighboring reaches. Initial treatments could be further manipulated in an experimental design to more closely examine coupling of geomorphic and hydrodynamic processes to desired biological processes.

The constructed channel (Figure 1) has a single-thread, meandering planform with riffles and pools, and a bankfull flow capacity of about 1,700 cfs. The channel width, gradient, sinuosity, and bed texture were designed so that this flow would generate bed-material transport to maintain riffles which are not clogged with fine sediment and which will gradually be reshaped into point bars. Growth of point bars is expected to drive channel migration and floodplain re-surfacing. Re-vegetation of the floodplain with native riparian plants began in February 2002, and will be supported by irrigation for 2-4 years.

Reservoirs upstream, especially behind New Exchequer Dam, which can store about 10^6 acre-feet of water, dominate the river hydrograph. The dams provide several opportunities for the proposed study. In April of each year, a constant, approximately bankfull flow is released for several weeks, allowing time for intensive campaigns of field measurement. Long periods of constant low flow also occur during critical life stages of the organisms to be studied. Any larger releases from the dam can also be planned for with enough time to deploy instruments and personnel from each of the study teams.

The restoration design was created after extensive interdisciplinary study [e.g. Stillwater Sciences, 2001a, b, 2002; California Department of Water Resources, 2001] and the incorporation of modern restoration concepts [U.S. Fish and Wildlife Service, 1997; Trush et al., 2000]. The design was well documented, and the project has also been carefully monitored since its inception with all data compiled electronically by the collaborating agencies. The CDWR [2003] monitoring program is the responsibility of Faulkenberry and his colleagues. We propose to augment the ongoing monitoring programs through more detailed measurements, targeted for answering the process-based questions posed in this proposal. The site has also been subjected to some empirical and modeling studies of flow and sediment transport (Alex Begaliev, CDWR), and of channel morphology and spawning use (Dr. Randy Mager, CDWR) since restoration. Dr. Mark Gard of the USFWS has implemented the River2D hydraulic model to assess the amount of spawning and rearing habitat at a range of discharges in the reach. These projects have been supported by the CALFED PSP, and we will collaborate with and build on the work of these investigators with higher-resolution models and measurements, including tracking and counting of fish and invertebrates, and with consideration of the sediment dynamics involved in controlling the evolution of the bed characteristics, the channel form and location, and the floodplain, and their effects on the populations of invertebrates, fishes, and plants.

Thus, the Robinson reach is an excellent laboratory for studying the relationships between physical habitat and biological response under a well-defined, common range of conditions relevant to river restoration. Measurements can be made under controlled conditions, but at actual field scale, and the evolution of the valley floor ecosystem towards a more complex, naturalized environment can be observed at high resolution. Moreover, experiments can be planned to observe the influence of: (a) gravel augmentation (large volumes of gravel have been stored on-site by the agencies in anticipation of this), (b) controlled flow releases; (c) engineered modifications of channel and floodplain form; and (d) irrigation of floodplain plants. During the first several post-project years, the channel and floodplain are expected to change slowly, so there is time to make a detailed study of physical and biological processes in their near-initial condition, and then to take advantage of later changes and manipulations to increase understanding over a wider range of conditions. It is difficult to find such a convenient and appropriate site for a multi-disciplinary investigation of how river restoration actually influences physical and biological processes and conditions.

PROJECT GOALS AND WORKPLAN

The overarching project goal is to answer the question posed at the beginning of the proposal in a quantitative manner, transferable to other sites in a form that is useful for other restoration projects. We will try to accomplish this goal through a set of parallel, interactive programs of field measurement and mathematical model construction. Specific goals, questions, and hypotheses for each component of the project are listed in the following sections, and may need to be modified after further consultation with agency personnel. Because the object of the restoration is to restore biological populations in the Merced River and elsewhere, we will synthesize most of our results in statistical and other mathematical models describing the response of channel and floodplain communities to the physical activities of channel restoration. Model construction will occur from the outset of the project, --- however simple the initial formulations. This action will require us to formalize our conceptual models, develop consistency between disparate data sets, identify critical variables, and communicate among ourselves and with collaborators and users in an exact manner. We expect those models to be refined as the study unfolds. Because the physical alterations of the site provide the template for all the biological studies and population modeling, the proposal begins with an outline of the research on the hydrodynamics and geomorphology of habitat creation and maintenance. We will then describe the proposed work on restoration of invertebrate communities, followed by the research on use of the reach by fishes and reestablishment of floodplain communities. We emphasize the nature of the research products and the ways in which they might support decision-making about restoration.

A. HYDRODYNAMICS AND GEOMORPHOLOGY [Dunne and Faulkenberry]

Description of the Topic

Most of the work in river and floodplain restoration involves manipulating flow and re-grading channels and floodplains to create more favorable conditions for certain ecological processes. However, most of the desired biological responses are predicted from fragmentary information, transferred from disparate sites, and the details of the hypothesized physical-biological interactions remain unquantified or untested. Design and assessment of river restoration projects could be facilitated if these interactions were understood well enough to improve the reliability of ecosystem-level predictions.

To characterize and explain the creation and functioning of the physical habitat we will concentrate on measuring the following features:

- the flow field of the in-channel water column
- flow within the channel bed
- the transport of suspended load (including organic particles and organisms)
- the transport of coarse and fine bed material
- the trapping of fine sediment within the coarse framework of the channel bed
- the microtopography of the bed surface
- re-shaping of the bed into pools, riffles, and bars by bed-material transport
- bank erosion and consequent channel migration
- overbank flow and deposition of fine sediment

We understand that subsurface flow within the floodplain is being monitored and modeled by other scientists.

Scientific Questions to be Addressed

- What are the patterns of flow depth and velocity throughout the restored reach at various discharges, and how are they affected by factors that can be manipulated in channel design and that evolve after project construction (such as channel geometry, bed texture, in-channel structure, bank roughness)?

- How do the temporal and spatial patterns of suspended load and bed-material load respond to the flow field and the constructed channel geometry to create biologically relevant changes of bed state and morphology?

- How do bar deposition and bank erosion combine to create patterns of in-stream habitat and drive re-surfacing of the floodplain?

Background

An investigation of how abiotic and biotic processes affect habitat components in a river system can be generally subdivided into three broad categories – (i) how processes and habitat components change when the riverbed is relatively stable; (ii) how a mobile riverbed affects processes and habitat components; and (iii) how the mobility of riverbanks affects processes and habitat components in the channel and floodplain. A conceptual model of the river channel and riverbed that provides a basis for understanding the importance of different processes affecting the river bed and the river channel during various flow conditions is described in the following two paragraphs.

Many river channels in the Central Valley of California have a channel bed consisting of a framework of coarse sediment particles (gravels and cobbles) with fine sediment particles (sands, silts) filling some of the interstices and also forming patches on the surface of the coarse framework. Channel banks cut in to these sediments may be reinforced to varying degrees by plant roots, allowing them to stand at near-vertical angles along parts of the channel margin; other parts of the channel margin are not reinforced, and slope gradually. Within a range of low flows, coarse sediment remains immobile and the water simply flows over a static riverbed, adjusting its depth and velocity gradients to the morphology. The only changes aquatic organisms experience at this stage are variations in depth and velocity. As flows increase, the patches of finer sediment are selectively mobilized and transported either in suspension or by rolling and hopping along the bottom of the bed. The river channel is still considered stable at this point because the coarser gravel framework is immobile. Fine sediments enter the reach and may settle out as new patches on the surface of riffles, settle into pools, or infiltrate into the bed. When discharge increases to near bankfull stage, but before water spills extensively onto the floodplain, the shear stresses exerted by the flow on the bed are usually high enough to begin selective mobilization of the gravel and cobble framework. As flow increases still further, shear stresses in the channel are high enough to begin reshaping the river channel boundary by eroding the banks and depositing sediment on the point bars that become assimilated into the floodplain. The interplay of these sediment transport processes results in a variety of ecologically relevant processes over the range of flows.

For example, the quality of spawning habitat in a stable riverbed will change over time as fine sediments infiltrate into the subsurface, fine sediments are deposited and remobilized from the surface, and female salmon dig up the riverbed for laying their eggs. On the other hand, flood events that can mobilize the larger gravel particles can either rejuvenate or scour away the redd. Thus, the condition of the spawning gravel is the result of a stochastic 'game' resulting from the sequence of suspended sediment concentrations and flow applied to the reach.

Quantifying the rules of this game provides a method for estimating the risk of the spawning gravel being in a variety of states under specified conditions, but this concept has only recently been applied to spawning gravels [Lang, 2004]. A similar approach can be taken to the temporal variation of microtopography that shelters juvenile salmon, strongly affecting their condition and mortality [Suttle et al., 2004]. When the coarse bed material moves, not only is the gravel either 'flushed' of or impregnated with fine sediment, but the morphology of the bed is molded into bars, pools and riffles, and into more complex forms around in-channel woody debris. It is to be expected that the relatively simple geometry of the restored channel will become more complex as a result of spatial patterns of bed-material transport, but the details of this process are difficult to predict. There is a need for detailed measurements of how this happens in a restored channel reach, and for an attempt to predict the remolding of the bed over time. At even higher flows, it is known that channel banks can be undermined, but the threshold flow conditions, spatial pattern, and rates of this process are not well understood; nor is the role of vegetation either in stabilizing the bank or invading the channel. Both quantitative descriptions and predictions of these effects for restored and un-restored reaches are needed. Other interactions between flow, sediment transport, and bed characteristics affect invertebrate populations and fish as detailed later.

Flow fields

There is a considerable body of literature on cross-section-averaged flow conditions through straight channel reaches, but relatively little documentation of complex flow fields in sinuous, natural reaches. Yet it is the goal of many river restoration projects to re-establish habitat complexity to channels [Brookes and Shields, 1994]. Availability of new instruments, such as the acoustic Doppler velocimeter and acoustic Doppler current profiler, and of new two-dimensional, vertically integrated flow models for complex bed topographies [e.g. Bates and Lane, 1999; Pasternack et al., 2004; or the new quasi-2D public domain model MD-SWMS, developed by the US Geological Survey for flow, sediment transport, and channel migration] allow realistic definition of flow conditions in which fish and invertebrates swim, float, feed, shelter, and reproduce. These flow fields also affect the patterns of sediment transport that mold the channel bed into spawning, rearing, and other kinds of habitat, as well as determine the amount, depth, and extent of any overbank flow [Trush et al., 2000]. **We are not familiar with a study of habitat formation and biological responses in which the local flow environment of all measurements and calculations is specified, but we intend to create such a simulated environment, interpolating between our own detailed measurements of the flow field at a range of discharges.** Such a model could then be queried to explore how alterations of channel geometry, bed texture, meander planform, and in-channel physical structure could alter the flow field and the amount of various habitat conditions. Field tests of the predictions could then be designed.

The amount of habitat can be quantified through a technique pioneered by Lamouroux et al. [1995, 1998], who demonstrated that point values of depth and vertically averaged velocity from a range of stream sizes and discharges exhibit similar probability distributions with parameters that vary with discharge. This insight yields one efficient metric of habitat quality that can be compared across discharges, over time, and between restored, un-restored, and natural channels.

Bed material sediment: condition, transport, and morphology

Aquatic habitat, created and maintained by sediment transport processes, can be categorized as: (i) macro-scale habitat units (e.g. pools and riffles for rearing and spawning), (ii) crosssectional shape (e.g. shallow margin habitat near point bars, pools, or bank overhangs that provides refuge for juvenile salmonids), and (iii) riverbed characteristics (e.g. a gravelly surface with varying amounts of fine sediment that creates hiding and resting spots for juvenile salmonids. In order to evaluate whether the restoration oft the Robinson reach will provide the habitats needed to support a healthy population of salmon over the long-term, the quantity and quality of all three habitat categories should be evaluated and linked to the flow and sediment transport processes that are necessary to sustain them, and that are manipulated by river restoration projects.

In the following sections we outline our specific approach for investigating (i) changes in the habitat under stable bed conditions, (ii) changes due to mobile riverbed conditions, and (iii) changes due to mobile riverbank conditions. Floodplain processes and their effects on habitat will be considered in a later section.

Methods

Flow fields

We will conduct detailed mappings of channel topography, water surface elevation, and flow depth at a range of discharges. The bed will be surveyed with a total station and flow depths will be mapped using an optical remote sensing technique developed by Legleiter et al. [2004], which should allow continuous digital mapping of flow depth from a low-flying airplane, significantly increasing the ability of restoration specialists to document habitat morphology over long reaches of river. The texture of the bed sediment will also be defined in detail (see below). Discharge is continuously monitored at the upstream end of the reach by the CDWR. Current speed and direction will be measured at many locations (number varying with discharge) within the reach at a range of discharges using the acoustic Doppler velocity meter and electromagnetic current meter.

The resulting three–dimensional descriptions of the flow field will be used for (a) defining habitat for the organisms studied by other components of this investigation ; (b) for calibrating a two-dimensional, vertically integrated, mathematical model of the flow field (initially River2D) so that the flow field can be estimated at other discharges; and (c) as a means of understanding how the river channel itself is molded by flow and sediment transport (see below on sediment transport and bank erosion). We will utilize the calibrated model to predict ways of altering the flow field by adding structure to the channel, and then testing the predicted velocity perturbations and measuring their effect on habitat use by various organisms at a range of discharges. The model would also facilitate the comparison of other channel designs for the Merced River and elsewhere, in the manner illustrated by Pasternack et al. [2004]. The research on flow documentation and modeling and its ecological significance will be conducted by a postdoctoral researcher.

The current simplicity of channel morphology, bed textural pattern, bank geometry, and floodplain topography in the Robinson reach provides an excellent opportunity for experimenting with the physical and biological effects of adding structural complexity to the system. For example, after the initial characterization of channel topography, flow field, bed sediment, and use of local environments by invertebrates and various fish species, we could collaborate with the responsible agencies to design various installations of large boulders, or anchored woody debris, or modifications of the channel-floodplain boundary. We could then model the expected influence of the structural changes on the flow field and check the predictions against measurements of depth and velocity changes at a range of discharge in order to test our ability to apply the method elsewhere. Our colleagues could then repeat their measurements of the use of the local environments by various organisms to measure directly the ecological significance of the structural modifications. We have similar ideas for experiments on the effects of locally altering the topography of the floodplain, its connection to the channel, and its elevation above the water table in order to measure their effects on plants and animals in a direct, experimental fashion. The initial simplicity of the Robinson reach would facilitate rapid accumulation of a large amount of such information for river restoration design, and the information could be transferred to other sites with the aid of the modeling effort.

Bed material condition, transport and morphology

We will conduct a high-resolution mapping of *substrate texture*. Recent studies demonstrated the utility of digital photography and image processing techniques for automated measurement of sediment grain-size distributions [Sime and Ferguson, 2003]. We will extend these techniques to a field situation to develop continuous maps of the streambed texture. A waterproofed digital camera will be used to acquire substrate images, adjusted to a common scale using a reference object and then combined into a mosaic. Image processing software can be used to estimate individual particle sizes and the fines content of the substrate. The image-derived estimates will be compared with weighed samples, and appropriate corrections applied to account for the difference between the exposed projection of a grain on a two-dimensional image and its actual three-dimensional geometry. The samples, obtained with surface scoops and with a standpipe modified for freezing cores [Barnard and McBain, 1994], will also be used to quantify the relationship between surface and subsurface texture, both for sediment transport predictions (see below) and for studying the effect of fines on spawning gravels (see below).

Microtopography of the gravel bed is another physical characteristic of ecological significance because it affects flow resistance, influences vertical velocity profiles and turbulence, and defines the habitat conditions for invertebrates and juvenile salmonids [Suttle et al., 2004]. We expect this microtopography to vary with average texture and sorting of the sediment, and therefore with position (shear stress) in the channel in a systematic way, and will be modified by surface accumulation of fine sediment. The detailed measurements needed to characterize microtopographic variability will be conducted on 1 m^2 sample hydrodynamic environments (characterized by their velocity profiles) with a surface roughness template consisting of a series of horizontal support bars and closely spaced vertical rods that reproduce a profile of the substrate by sliding up and down freely when placed on the bed. This profile can be captured by taking a digital photograph of the rods, with the horizontal support bar serving as a scale object, resulting in a form of habitat description relevant to studies such as that by Suttle et al. [2004], who measured the survival and condition of juvenile fishes living over gravel beds that had been inundated with various amounts of sand. The seasons of measurement will be coordinated with the surveys of invertebrates and juvenile fishes, in order to develop a mathematical model of how the bed surface condition varies with time during critical life stages of the organisms

The f*ine sediment content of spawning gravels,* along with their *hydraulic conductivity,* and the *dissolved oxygen content of the percolating water* are known to affect spawning success of fishes as well as populations of invertebrate organisms. Hydraulic and physical bed characteristics affect where adult salmon choose to spawn [Geist and Dauble, 1998], how many eggs survive into alevins [Chapman, 1988; Groot and Margolis, 1991], and how many fry emerge from the substrate [Chapman, 1988; Groot and Margolis, 1991]. Subgravel flow, along with adequate dissolved oxygen of the percolating water, are known to affect both where salmon choose to spawn [Geist and Dauble, 1998] and the survival of salmonid embryos [Chapman, 1988]. Fine sediment content of the bed not only affects the subgravel flow rate but can physically block the emergence of fry from the gravel bed [Chapman, 1988]. These indices of habitat quality will be measured using a modified standpipe [Barnard and McBain, 1994]. A dense survey of this kind at the beginning of the study will measure the effects of approximately five years of flows since the restoration, with some knowledge of where and how frequently the bed has been scoured, supplied by existing surveys of 24 channel cross sections (CDWR monitoring program). Sampling of fines content will then be repeated in the autumn of each year; sample numbers will depend on the variability that we encounter.

We will install batteries of radio-tagged tracer gravels and scour chains in the channel bed (3 per cross section on five cross sections) to establish the critical flows and stresses required for mobilizing various parts of the bed, and with these data we will test our ability to predict the threshold of bed-material motion from theory [Buffington and Montgomery, 1997]. We will also deploy geophones buried along the channel margin to record the acoustic signal of this mobilization and of vibrations that may lead up to the mobilization. At the scour chain sites, we will also bury cans in the bed and retrieve them before each spawning season to measure the infiltration of fine sediment [Lisle, 1989]. We intend to construct a hydraulic model of fines accumulation in the bed between flow-driven scour events, and to relate the fines content to reductions in measured hydraulic conductivity. We will also conduct local experiments releasing slugs of fine sediment upstream of some of the measurement sites to extend our data beyond the local range.

At each site where we study the accumulation of fines, we will make regular measurements of near-surface fines transport with a Helley-Smith bedload sampler on a frequent enough basis to capture selective transport of fine bed material and test our ability to predict it with a conventional bedload equation [Wilcock and Kenworthy, 2002]. We will also monitor the transport of suspended load into the reach with a USDH-48 suspended load sampler to keep track of changes in supply. We will measure vertical velocity profiles over the scour and fine-sediment accumulation sites at a range of low to medium flows and use them to check the value of the vertically averaged two-dimensional flow model referred to above for predicting the localities of fine sediment accumulation and scour. In this way, we intend to relate the accumulation and flushing of fine sediment in the bed to the larger scale environment of the restored reach and to the history of flows to understand how fine sediment accumulation responds to these design factors. Later studies, or comparative studies by colleagues involved with other CALFED restoration projects, could test our predictions by means of rapid surveys of fine sediment in spawning gravels with a modified stand pipe. The study of fine sediment accumulation and release, and its effect on habitat conditions will form the Ph.D. thesis of Aleksandra Wydzga, who will have completed all degree requirements except for the thesis, and be able to work full-time on the project. She is also an unpaid collaborator in the Stillwater Sciences/UC Berkeley flume study of sediment transport, funded by CALFED, and she will be able to form a link with that project by which some measurements made in the flume might be repeated at natural scale in the Merced River.

Larger-scale remolding of the coarse bed material into bars, pools, and riffles as the restored reach becomes more complex will be studied through regular topographic surveys after each flood season, extending and increasing the density of the cross sections regularly monitored by the CDWR since the original construction. We intend to survey a sufficient density of points to develop high-resolution digitial elevation models from which to make morphologic estimates of bed material transport rates [Lane et al., 1995; Ham and Church, 2000]. Geostatistical techniques [Goovaerts, 1997] will be employed to interpolatie elevation points and differences explicitly quantify the uncertainty in the measurement of morphological change and thus morphology-based estimates of bed material transport. This approach is particularly advantageous when morphological techniques are applied over short time scales at low transport rates, which will often be the case in river restoration projects. Both travel distance and sediment budget-based methods (Gaeuman et al., 2003) of obtaining transport rates from morphologic data will be evaluated using tracer gravels and direct bedload measurements at the upper end of the reach, respectively. The morphological estimates of transport rates will be compared to traditional measurements that we will make with a Helley-Smith bedload sampler at local scales, but the former have several advantages, including their spatial extent over the entire reach and their incorporation of the effects of channel-bed morphology on local, effective shear stresses and transport rates.

We will attempt to calibrate a bed material transport equation specific to the Robinson reach by using a sediment transport rating curved based on Helley-Smith sampling at the upper end of the reach to invert the morphology-based estimates. For this inversion, we will initially use both the flume-based equation developed by Wilcock [2001] for sand-gravel mixtures and the Engelund-Hansen equation that Singer and Dunne [2004] re-calibrated with field measurements on several Western gravel-bed rivers. We will also attempt to route the bed material through the reach and model the resulting changes in bed topography using a cellular model of flow and sediment transport [Thomas and Nicholas, 2002]. The RIVER2D model and the empirical mapping of flow fields described above will be used for verification. A simple channel such as the Robinson reach presents an attractive first target for examining whether the morphology-based method will allow us to explain the small amount of change that has already occurred and to make high-resolution predictions of the effects of gravel augmentation that could then be tested by a designed experiment.

As a check on the bed material transport computations, we will track a large sample of gravel particles tagged with magnetic tracers, which can be installed and monitored continuously during each spring's high flow or during higher discharges that cannot be predicted at the present time. We will use the tagged particles to develop an empirical relationship between travel distances and shear stresses along paths computed from the flow model, and the resulting relationships will be used in an alternative method for obtaining a transport equation through inversion of the bed morphology surveys. Our various attempts to produce a sediment transport model should yield results that are directly useful for the design of gravel augmentation projects in the Robinson reach, and our larger goal will be to produce a model that can be applied to similar sand-gravel bed rivers in the region. The research on the re-molding of the channel bed by sediment transport will constitute the Ph.D. thesis of Carl Legleiter, who will work full-time on the project, supported by a research fellowship from external funds.

Bank erosion and channel shifting will be measured after each high-flow season, extending the 24 post-restoration cross-section surveys by CDWR. We will also make a higher-resolution visual mapping of undercut banks each year to define the evolution of near-bank habitat. We expect the pattern of small-scale bank erosion features to foreshadow larger-scale bank erosion and channel shifting. We will then attempt to predict this pattern of bank erosion and bar formation on the opposite side of the channel by a number of strategies. We will implement the FLUVIAL-12 quasi-two-dimensional model of flow and sediment transport [Chang, 1988] or the new US Geological Survey model MD-SWMS referred to above to compute bank mobility as a result of the flow and sediment budget for the channel. Such a procedure would later allow the modeling of gravel augmentation strategies on channel morphology as well as bed texture. These predictions could then be tested with an experimental release of sediment at a time appropriate for project management. If successful, the research would produce a useful tool for extending results to the design of channel form and gravel augmentation projects elsewhere. If the sediment-budget-based modeling of bank erosion, bar formation, and channel migration is not successful, we will calibrate the Ikeda et al. [1981] bend theory to the reach, based on the small observed changes, and use it to forecast a testable pattern of channel migration, bar formation, and floodplain resurfacing affecting the development of the floodplain vegetation. This work will be conducted by the postdoctoral researcher.

Overbank sedimentation, which is likely to be rare and small for the first few years, will be monitored by means of clay pads, and modeled as an overbank transport process, based on computations of overbank flow (see earlier on flow modeling) and the computed vertical profile of suspended sediment concentration [Dunne et al., 1998; Malmon et al., 2004]. However, we will pay particular attention to detailed sampling of deposition within the riparian vegetation where it may have an ecologically significant soil-building role even in the short term. The research will require a small amount of occasional fieldwork.

Products

We intend to produce detailed quantitative descriptions of the physical habitat and the processes that create and sustain it, so that measurements of various biological processes, described in other sections of the proposal can be related to the spatial extent and timing of physical conditions. The physical characteristics to be studied were chosen for their direct relevance to biological processes. We also intend to construct mathematical models of: the flow field; morphology and sedimentological characteristics of the channel bed; and channel mobility, as they are affected by flow, sediment supply, bank conditions, the initial restored condition of the reach and various manipulations such as flow and gravel supply to which the channel may be subjected in future management actions. With these tools, we will consider management strategies and how they might affect the production and maintenance of habitat in the Robinson reach and elsewhere.

As the channel evolves, we expect the diversity of physical habitat to increase, and we should be able to predict, track, and explain such changes, or continue to refine our understanding. Our results should also facilitate the design of future management actions, including gravel augmentation, flow regime management, or new restoration projects by helping to predict not only the physical habitat changes, but also the interactions between physical change and the biological processes studied by the collaborating team. We expect to develop biologically relevant metrics of how much habitat of various quality is evolving inside the Robinson reach, and how this progression relates to the controlling variables (both natural and those subject to design and management).

B. RESTORATION OF INVERTEBRATE COMMUNITIES [Lenihan]

Description of the Topic

This portion of our collaborative proposal explores specifically how the modification of physical characteristics, including the re-scaling of channel dimensions to available flows, altering of channel bed material and geomorphology, encouragement of channel migration, and the re-establishment of floodplain plant communities, affects macroinvertebrate communities and other components of the Merced River food web that supports juvenile chinook salmon, and other salmonids and native fishes.

Invertebrate species provide a critical energy source for salmonids and other native fishes in river food webs. Juvenile salmon and steelhead trout (*Oncorhynchus spp.)*, California roach (*Hesperoleucas symmetricus*) and three-spined sticklebacks *Gasterosteus aclectus*), among other fish species, prey on benthic, water column, and surface-dwelling macroinvertebrates, including various species of insects, gastropods, crustaceans, and their larvae [Allan 1995]. Fish and invertebrates are embedded in food webs that consist generally of benthic algae (e.g. chlorphtyes, diatoms, and cyanobacteria), primary consumers or herbivores (e.g. haptageniid mayflies, chironomid and Dixid midges, and caddis flies), secondary consumers or carnivores (Odonates-dragonflies, Plecopterans-stoneflies, and Meglopterans-dobsonflies), and fishes that are tertiary consumers [Power 1990, Power et al. 1995]. Adult salmonids and other fishes also prey on juvenile and small fishes that, in turn, prey on invertebrates [Power, 1992]. Benthic invertebrates, especially those living in redd sediments, may prey upon salmon eggs. Finally, juvenile and small adult fishes also prey on river zooplankton, which consists mainly of Copepoda, Cladocera, Diptera, Amphiopoda, Oligochaeta, Coleoptra, Collembola, Decapoda, and larva or nymphs of Epemeroptera, Hemiptera, Lepidoptera, Mollussa, Odonata, Podocopida, and Trichoptera. River geomorphology and hydrodynamics influence the abundance, distribution, and population dynamics of macroinvertebrates directly through effects on dispersal, recruitment, habitat use, and resource availability; and indirectly by modifying species interactions such as competition, predation, and facilitation [Allan, 1995; Palmer and Poff, 1997; Hart and Finelli, 1999]. **Understanding how physical processes influence invertebrate populations, and examining trophic links between invertebrates and fishes, provides a means of coupling river restoration with the population dynamics of salmonids and other native fishes.**

Large–scale habitat restoration, like that in the Merced River, provides an unprecedented opportunity to examine experimentally how physical mechanisms influence the composition, trophic structure, and dynamics of food webs that influence fish populations. Ecological processes in any ecosystem are influenced by multiple environmental drivers, which can interact in complex ways [Powell, 1989; Lenihan and Peterson 1998]. Identifying cause-and-effect relationships between physical drivers and population and community responses requires one to examine processes at different spatial and temporal scales, utilize hierarchically designed field studies, and synthesize information using various modeling techniques. Accordingly, large-scale experimental studies of physical-biological coupling are rarely attempted [Powell, 1989]. Rarer still are studies designed in an adaptive management framework to evaluate the processes modified in restoration programs [Palmer et al., 1997; but see Lenihan, 1999].

The few studies that have successfully examined physical-biological coupling in river or estuarine food webs [e.g. Power et al., 1995; Lenihan et al., 2001] have integrated large-scale experimental manipulations of physical variables (e.g. substrate type and flow regime) with large-scale sampling and small-scale experimental manipulations of demographic responses of target populations. Missing are integrated multidisciplinary studies of how modification of river geomorphology, flow, and their interaction influence demographic responses of invertebrates and the habitat they require; how demographic responses control invertebrate population dynamics; and how variation in invertebrate populations influence food webs that sustain salmonids and other native fishes [Allan, 1995; Hart and Finelli, 1999]. We propose to employ this integrated research framework in a sampling, experimental, and modeling program designed to identify mechanisms by which rehabilitation efforts influence ecological function in the Merced River. The work would be conducted by H. Lenihan and a postdoctoral researcher in Ecology.

Scientific Questions to be Addressed

We propose to address the following questions in an interdisciplinary research program that will take advantage of the unprecedented definition of hydrodynamic and geomorphological conditions and processes in a restored river:

Over-arching question: *How do restored hydrodynamics and channel bed dynamics influence macroinvertebrate populations, predator-prey interactions between macroinvertebrates, juvenile chinook salmon and other native fishes, and the structure of food webs in the Merced River?*

Specific questions for analytical design:

1. *How do the species composition, population abundance and demographics, and trophic structure of macroinvertebrate communities in the restored portion of the Merced River vary with small-scale (1-10 m) physical features (flow velocity, bed sediment, benthic plant community composition), large-scale (10-100 m) physical features (channel cross section, water depth), and time (seasons, floods, and temporal changes in bed texture, plant communities, debris, and flow conditions)?*

2. *How do species interactions among macroinvertebrate, juvenile Chinook and other salmonids and native fishes vary with small- and large-scale physical features of the river, and with temporal changes in physical features?*

3. *How do temporal changes in physical features of a river influence the structure of food webs that support salmonids and other native fishes?*

Methods

To address these questions we will conduct:

1. a sampling program to identify relationships between physical characteristics (measured and related to watershed-level controls and restoration design by our collaborators) and food web components, including macroinvertebrates;
2. manipulative experiments to quantify physical-biological interactions
3. description and modeling of food webs to integrate the physical and biological information for use in predicting long-term consequences of different geomorphological conditions and alternative river management strategies

The study will aim specifically to provide quantitative guidance on ways of promoting favorable populations of prey for salmonids and other native fishes in future restoration projects in the Merced and similar rivers.

1. *Community patterns: sampling and statistical analysis*

Identifying correlations among community composition, trophic structure, and the local physical characteristics of a river is a first step in understanding physical-biological coupling. The sampling program would be designed to (a) measure variation in common community parameters (abundance, species richness, and trophic structure) of benthic and zooplankton macroinvertebrates and (b) estimate how much of that variation is explained by geomorphology (channel cross section, reach, microhabitat, and substrate type), flow (velocity and turbulence), and temperature. We will also measure how invertebrate communities co-vary with organic matter (periphyton, macrophytes, and organic debris) and local fish abundance.

River invertebrates are usually divided into feeding groups representing, for example, shredders, gougers, suspension-feeders, deposit-feeders, grazers, and predators. Species within each trophic group inhabit the benthos, water column, and water surface. We plan to sample invertebrates from each habitat type in four replicate pools and riffles along five reaches of the Merced River: immediately upstream of the restored Robinson Reach; the first 250 m of the Robinson Reach where the channel gradient is 0.0029; a middle section of the Robinson reach where the gradient is 0.0023; a lower section with a gradient of 0.0017; and a 250-m reach located just downstream of the restored section. We also plan to sample salmon redds identified by agency biologists and by Healey in another section of the proposal, and locations down river that have experienced anthropogenic inputs of sediment, which can have profound influence on invertebrate and salmonid population biology. We expect that the differing gradients (and sediment inputs) will affect sediment transport and the evolution of the bed state (texture and packing) and morphology (bar accumulation), as identified and explained in the physical habitat study. In each pool/riffle combination within a reach, we will employ stratified random sampling to collect invertebrate community samples using a variety of sampling methods, including plankton nets, sweep nets, drift nets, kick nets, core sampling, and diver counts within quadrats or along transects placed on the river bottom. We will quantify species composition, abundance, size frequencies, and biomass. To quantify algal abundance and biomass on the river bottom at locations where invertebrates are sampled, we will record the percent cover and take algal scrape samples from 6 replicate 49 cm^2 areas, primarily on rocks and cobbles at locations where alage usually grow. All invertebrates collected in the field will be procured in 10% buffered formalin, returned to the lab, and sorted by trophic group, taxa, sex, and size categories. Plant samples will be procured and later analyzed for dry weight and total Chl a concentration.

The percent cover of each substrate type (sand, pebble, cobbles, organic debris) will be recorded for each benthic invertebrate sample. Percent cover will be estimated from direct counts or from digital underwater photographs of each substrate type. Flow speed will be recorded during high and low flow seasons across each substrate type, in mid-water, and near the surface over 10-minute periods at each site that is sampled for invertebrates. Flow samples will be taken with an Acoustic Doppler Profiler (ADP), which will also be used for the high-resolution flow field studies. The ADP will also measure water depth and temperature. Measures of turbulence at each sampling station will made based on multidimensional velocity profiles recorded by the ADP [Allan, 1995; Lenihan, 1999]. The ADP will also be used to monitor flow in our manipulative experiments. Sediment grain size will also be measured as described in Hydrodynamics and Geomorphology section of this proposal. All invertebrate and plant sampling will be conducted in different flow conditions, seasons, and after significant disturbing flows.

To test whether community responses (total abundance of each taxon, feeding groups, species richness, size frequencies, and biomass) within each habitat type (benthos, mid-water, and surface) vary with location (i.e. pool vs. riffle) and site (i.e., reach) in the Merced River, a three-way hierarchically-nested ANCOVA with habitat type nested within location, location nested within reach, and flow characteristics as a covariate. Multiple regression and Principal Components Analysis will quantify relationships between physical variables, including flow speed, temperature, algal biomass/Chl a concentration, and organic matter content. The emphasis of these studies will be on developing predictive relationships that can be applied to, and tested at other sites, and used to guide manipulative experiments.

The interpretation of habitat use by macroinvertebrates (and fish, see later) could be enriched the geostatistical work on flow fields and bed texture and morphology, described in Section A of this proposal to establish a quantitative link between hydraulic complexity at a range of scales and the habitat utilization by invertebrates or fish. For example, we hypothesize that a reach with greater small-scale variability in depth and velocity (which can be summarized with a variogram) will tend to have a greater diversity of insects. Fish diversity and numbers might respond to habitat complexity over another spatial scale. The same idea could be extended to the assembly of the floodplain plants communities, and would be easy to implement because of our tightly organized team approach to the field work.

2a. *Experiments on invertebrate population demographic responses*

Cause-and-effect relationships between physical drivers and community structure and composition are best revealed by identifying how specific factors, or combinations of factors influence demographic rates of individual organisms. Key demographic rates that underlie changes in population abundance, and therefore variation in community composition, are births, recruitment, growth, reproductive output, dispersal (emigration-immigration), and mortality. Quantifying demographic rates allows for the creation of population dynamic models in order to explore relationships between river characteristics and responses in invertebrate communities.

We propose to explore how key habitat features influence population responses of invertebrates using a suite of manipulative field experiments, consisting of mesocosm-flumes that are designed to control water depth, flow speed (using in-situ flumes pioneered by [Cooper and Baramuta, 1993]), bed type, organic debris content, and algal growth. The structures would provide the means to test relationships interpreted in our sampling program. The flumes (4-m long x 1.5-m wide; rebar supports, plexigalss sides that extend above surface water and control light penetration, and mesh entrance and exit ports) are designed to modify relative flow speed [Cooper and Barmuta, 1993]. One set of flumes increases ambient flow by forcing a larger volume of water to flow within their borders via a funnel-shaped up-stream opening. A second set of flumes retards ambient flow by baffling water before it enters the enclosure. A third set of flumes acts as a control by not influencing flow speed. The goal of these experiments is to identify how specific hydrodynamic and geomorphological features interact to influence demographic rates of a circumscribed set of invertebrate species representing different feeding groups. For example, if the abundance of gammarid amphipod grazers (i.e. important prey for juvenile chinook salmon) on the benthos in deep pools is found to vary in response to substrate type (e.g. coarse gravel vs. mixed pebble-sand) in the restored Robinson's Reach; to organic debris in the un-restored downstream reach; and to flow speed in both pool-reach combinations, we will design and conduct an experiment that entails an orthogonal manipulation of these three factors to test management options to maximize gammarid abundance. Such an experiment would entail the measurement of recruitment, growth, and survivorship of individual gammarids that colonize replicate rocks of similar dimensions that support different levels of algal growth (e.g., zero, 10%, 50%, and 100% cover) outplanted on to different substrate types (e.g., coarse sand vs. gravels of various size), that, in turn, are situated within the mescosom flumes. Twelve mesocosm-flumes would be required (one for each treatment combination) and the experiment would be repeated (i.e. blocked) through time to provide replication. Multifactor MANOVAs or MANCOVAs would be used to detect differences in various demographic responses among treatments (including the effects of predator-prey interactions among invertebrate species). The specific questions to be addressed in the experiments will be driven by the patterns observed in the community sampling.

2b. Experiments on predator-prey interactions among invertebrates and salmonid fishes

Top-down control through predation by fishes, and bottom-up control through primary production control invertebrate population dynamics in river food webs [Power, 1990]. Habitat heterogeneity and flow can influence both top-down and bottom-up processes [Power et al. 1995; Hart and Finelli, 1999]. Work in Northern California rivers indicates that while fish forage for invertebrates in two major habitat types, on (1) rocks and boulders and (2) on gravel and sediment bottoms, predation by fishes significantly affects invertebrate populations only on rocks and boulders [Power, 1992]. However, effects of fish foraging in gravel and sediments have not been adequately examined as a function of flow conditions, channel configuration, sediment type, and organic debris content. In addition, we know little about the effects of invertebrate predators on salmon eggs in redds. We propose to use a series of experiments using fish predator enclosure and exclosure mesocosms-flumes to examine how changes in physical habitat structure at different spatial scales, flow, and the structure of food webs (e.g., three-level vs. four-level food chains) influences predator-prey interactions among invertebrates and fishes. We will also test with experiments whether invertebrate predators influence salmon egg hatching success in varying flow and substrate conditions. These experiments are designed to identify what factors or interaction of factors affects the distribution and abundance of macroinvertebrate prey species, and predation rates of salmonids, especially juvenile chinook. In addition, rates of predation among different trophic levels recorded in these experiments will be used in food web modeling.

To test whether substrate type, flow, and fish predation interact to influence macroinvertebrate species in the Robinson Reach, we will install replicate large pens, pen controls, and open pens on replicate bottom areas in different locations of the river (pools vs. riffles vs. banks), with different substrate features (boulders vs. rocks; gravel vs. fine sediment), water depths; and flow speeds. Pens will be similar to those used by Power [1992]: 6 m^2: 3-m long x 2-m wide x 1.5 m tall; 3-mm mesh; and constructed of plastic screen lined with black plastic shade cloth. Juvenile salmon, and adult roaches or three-spined will be placed into pens (enclosures). Pen controls will be used to exclude fish predators (exclosures). Open cages will used to examine the effect of cage structure (controls). The species composition of algal and invertebrate communities and demographic responses of invertebrates will be examined in the different cage treatments. Flow speeds will be measured with the ADP..

In one set of experiments, we will allow natural invertebrate communities to be established on rocks and in surrounding sediment, and record changes in the populations of species known to be important fish prey or functional members of the food web (algae, primary consumers, and secondary consumers) over periods of days to weeks. In a second set of experiments, we will add known numbers of marked invertebrate individuals from each trophic level within the cages and measure their survival over short-time intervals (3-12 hours). Benthic algal (cynaobacteria, chlorphytes, and diatoms) percent cover and biomass will be sampled non-destructively in each replicate cage treatment. We will also sample zooplankton communities in the different cage treatments. This experiment will be conducted under high- and low-flow conditions, and through time as river geomorphology changes, for example, after major flooding events. In a third experiment, conducted in a set of fish exclosures placed on salmon redds identified in Healey's portion of our study, we will test the effect of invertebrate predation on salmon egg hatching success. Salmon eggs will be placed in redd sediments of different grain size and organic content, and with different flow speeds, that contain natural populations of infaunal invertebrates and matching sediments from which invertebrates have been removed. Data from these experiment will be used (1) to describe the structure of food webs as it changes temporally with the larger scale physical characteristics of the river; (2) to quantify the relative effects of within-river location, substrate type, flow, algal cover, fish predation, and number of trophic levels (three vs. four) on invertebrate populations in Robinson's Reach; and (3) to produce feeding rates that can be used in food web modeling (see below).

3a. Isotopic Analysis of Food Web Structure

Stable isotope analysis will be used to examine the structure of the river food web in the initial stage of our research, and periodically throughout time as physical characteristics change. Our objective is to use stable carbon and nitrogen isotope ratio analysis of consumers of varying trophic status to evaluate the relative contribution of different algal species, detritus, macroinvertebrates, and small/juvenile fishes to the food web that supports salmonids in the portions of Robinson's Reach. To identify carbon and nitrogen sources used by various consumers, we will measure the isotopic composition of natural populations of various species in the food web in the different portions of Robinson's Reach that will be sampled for invertebrate communities. The use of stable isotope ratios in food web studies is well established and the merits and limitations of the technique are reviewed in Fry and Sherr [1984], Simenstad and Wissmar [1985], Currin et al. [1995], and Peterson et al. [1985]. The carbon isotope ratio (expressed as ^{13}C in $^{0}/_{00}$) of a consumer closely reflects the ratio of dietary carbon [Fry and Sherr, 1984] whereas the stable nitrogen isotope ratio is typically enriched in ^{15}N from 2 to 4 $^{0}/_{00}$ relative to dietary nitrogen [DeNiro and Epstein, 1981; Peterson and Fry, 1987].

3b. Food web modeling

Results of community sampling, demographic measurements, predator-prey experiments, including the biomass of each trophic level and biomass transfer through grazing and herbivory, and isotope studies will be used to erect food web models designed to predict, among other things, the total biomass of salmonids that can be sustained under different river configurations. Food web models will be generated using the EcoSim food web model developed by Walters et al. [2000]. This model and its variations (e.g. EcoSpace) provide a powerful tool to examine variation in biomass and production within different trophic levels as they respond to variation in resource levels, species interactions, disturbances, and habitat structure. Our objective is to model the food web of the restored portion of the Merced River, and then to observe how the food web responds to fluctuations in flow regimes, habitat characteristics, species composition, and trophic structure of invertebrates and fishes. EcoSim modeling will allow us to estimate the long-term effects of changes in the abundance of fish and prey populations.

Products

The research program is designed to help us understand and predict the population and community responses of macroinvertebrate communities to variation in restored habitat characteristics, and to changes in fish populations, as they evolve and become more complex over time. This is critical for understanding population dynamics of salmonid and other native fishes. Our sampling program will establish a baseline for monitoring invertebrate communities on the restored reach, quantify environmental controls on invertebrate populations, and measure the relative influence of geomorphology, flow and predator-prey dynamics on food web structure in the Merced River. Our experimental studies will elucidate mechanisms that explain relationships identified in our sampling program, including how the engineered geomorphology and hydrodynamics influence invertebrate population dynamics and species interactions. Modeling will simulate the response of invertebrate species to larger-scale and long-term changes in environmental drivers, and to explore how management strategies (further physical modifications of the river, removal of nonnative species, stocking of fishes) might influence food web dynamics. Findings from this research component will relevant to river restoration design in the CALFED region and in other Mediterranean-climate systems in California and elsewhere.

C. EFFECTS OF RESTORED PHYSICAL PROCESSES ON FISH ECOLOGY AND BEHAVIOR [Healey and Kendall]

Description of the Topic

The larger objective of this research is to understand and develop models of the relationships among: (i) physical forcing of habitat attributes in stream reaches; (ii) associated biotic processes (plant and benthic invertebrate production and distribution); (iii) the use of the habitat by the local fish community, and (iv) the consequent impacts on fish population dynamics. Understanding these relationships has been a long-standing objective of river ecologists. However, as Armstrong et al. [2003] point out: “By drawing on published data it is possible to divine broad ranges of acceptable conditions for the life stages of each species. However, it is not possible to partition this variation into between-population differences, within-population preferences, within-population tolerances, and effects of interactions between habitat variables.” In a thoughtful examination of the state of habitat modeling, Hardy [1998] acknowledged that: “... integration of all the pieces has yet to be accomplished, field validation remains unproven, availability of an integrated analysis framework (i.e. computer software system) is not yet available, and a clear framework for selection and application of specific tools has not been developed." Hardy [1998] concluded with a plea for a broader collaborative effort between biologists, engineers and resource managers. **A fundamental premise of our research is that, as a team of physical and biological scientists, engineers and resource managers we can make significant progress in the integration that Hardy was looking for.**

The Robinson Reach provides a unique platform on which to investigate the processes connecting physics to fish. Because Chinook salmon is a focal species for the restoration, the majority of questions posed address aspects of the life history of salmon. However, the reaches also provide habitat for other native species about which very little is known. Our research on these species will be of a more exploratory nature [Brown and Ford, 2002].

Scientific Question to be Addressed

Overarching Question: *How do chinook salmon and other native fish species make use of habitat characteristics and functions in river channels and floodplains, and how do their behavior, energetics, and population dynamics respond to changing environmental conditions, especially after channel restructuring?*

Specific questions for analytical design:

1. *What is the relationship between selection of spawning sites by female Chinook salmon and substrate characteristics and flow field and water quality at tributary, reach and local scales?*
2. *How is survival of eggs related to physical, chemical and biological characteristics in the vicinity of the redd?*
3. *What is the relationship between juvenile salmon habitat use and substrate and flow field characteristics at the reach and local scales and how are these modified by food availability?*
4. *How do the characteristics and extent of various habitats contribute to the net production of chinook salmon smolts within the Robinson reach?*
5. *How do habitat quality and the patterns of habitat use affect the growth of juvenile salmonids?*
6. *What is the relationship between the distribution and abundance of non-salmonid native fishes within the Robinson reach and substrate, flow field, cover, and food availability? How do the spatial patterns of these variables and resulting fish movement interact to influence population dynamics of these species?*

1. W*hat is the relationship between selection of spawning sites by female chinook salmon and substrate characteristics and flow field and water quality at tributary, reach and local scales?*

This question has been studied mainly at the reach or local scale [Healey, 1991]. At the tributary scale, observations suggest that fish tend to move to upstream spawning areas first and move downstream again as the upstream areas become filled with spawners. However, this is not an absolute rule and different segments of a run may do different things. At the tributary scale, our research will depend heavily on collaboration with CDFG personnel, who have conducted tributary-scale monitoring of spawning chinook for many years. At the reach scale, emphasis has been on depth, velocity and substrate characteristics as factors determining suitability of habitats for spawning [Bjornn and Reiser, 1991]. Habitat suitability assessment based on these parameters has, however, had mixed success [Shirvell, 1989; Gibbins et al., 2002]. Selection at the local scale has also been related to flow, depth, substrate, and subgravel flow [Tautz and Groot, 1975; Bernier-Bourgault and Magnan, 2002]. Each of these variables will be measured.

2. *How is survival of eggs related to physical, chemical and biological characteristics in the vicinity of the redd?*

Siltation of redds resulting in slow percolation of water through the gravel is a frequent cause of poor survival of salmon spawn [Bjornn and Reiser, 1991]. The well-sorted gravels of the restored reach and the low amount of fines entering the reach suggest that egg survival should be high in Robinson Reach. However, other factors are known or suspected to play a role in egg survival, such as predation and disease, and these have not been well studied. Recent evidence also suggests that even small amounts of silt, if it is deposited at the bottom of the egg pocket, may cause high mortality [Meyer 2003]. Fine sediment accumulation and its effect on subgravel flow will be studied and related to hydrodynamics and channel morphology in conjunction with the physical component (A) of this study. Flow-related mortality of embryos in the redd is often identified as an important factor in population viability [e.g. Jager et al., 1997] but the mechanism remains uncertain. We plan to study embryo survival and associated physical and chemical conditions directly. Temperature, DO, and TDS will be monitored continuously during the incubation period in a sample of redds.

3. *What is the relationship between juvenile salmon habitat use and substrate and flow field characteristics at the reach and local scales and how are these modified by food availability?*

Detailed work has been done on the daytime use of habitats by some salmon species but not juvenile chinook. Distributions in relation to flow and substrate are size-dependent but also related to food availability and social relationships within the group of fish. Fausch [1984] hypothesized that stream dwelling salmonids occupy locations where they can obtain maximum net energy gain from foraging. The choice of specific habitats is influenced by physical attributes, food availability and predation risk, and the response of fish to these factors is modified by size and age [Giannico and Healey, 1999; Reinhardt and Healey 1997, 1999]. Social status is also important, however, and individuals adopt different tactics for getting food depending on social status [Neilsen, 1992].

Day and night distributions of juvenile salmon and other fishes are known to be very different [Helfman, 1993; Heggenes and Dokk, 2001]. However, the relationship between day and night distributions and whether individual fish typically move between the same locations on consecutive days has not been determined. Chinook also undertake seasonally concentrated redistributions to different habitats [Healey, 1991]. In larger rivers these redistributions can take fish into and out of tributaries and downstream.

4. *How do habitat quality and the patterns of habitat use affect the growth of juvenile salmon?*

A juvenile fish uses assimilated food to provide energy and resources for basal metabolism and respiration, active behavior such as swimming, and growth. Since food uptake is not continuous, some energy also is stored in reserves, which are drawn upon later. Dynamic energy budget (DEB) models provide a framework for integrating the feeding, behavior, and physiology of the fish to understand how fast it can grow under various (and variable) environmental conditions [Kooijman, 2000, Nisbet et al., 2000, Fujiwara et al., 2004]. The energetic structure of juvenile salmon has been well studied [e.g., Rombough 1994, Azvedo et al., 2004], and statistical techniques have recently been developed to estimate parameters of DEB models from longitudinal data on growth [Fujiwara et al., 2005].

5. *How do the characteristics and extent of various habitats contribute to the net production of Chinook salmon smolts within Robinson Reach?*

A detailed simulation model that links Chinook adult spawning, egg and alevin survival, and fry growth and maturation to environmental features was developed by Jager et al. (1997). This model has been used to explore effects of management strategies and climate change on Chinook productivity [e.g., Jager et al. 1999, Jager and Rose 2003]. This model has only been tested against relatively sparse data [Jager et al. 1997]; we should be able to collect a particularly rich data set for testing through the detailed, interdisciplinary investigation of the Robinson reach.

5. *What is the relationship between the distribution and abundance of non-salmonid native fishes in the Robinson reach and substrate, flow field, cover and food availability? How do the spatial patterns of these habitat variables and resulting fish movement interact to influence population dynamics of these species?*

The ecology of native fishes in California rivers is poorly known, and understanding their distribution and habitat use is complicated by the presence of large numbers of non-native invasive species [Brown and Ford, 2002]. Native species appear to be most successful in rivers subject to the least flow regulation or other human alteration. Most conservation and restoration emphasis in the Central Valley has been on salmonids with relatively little attention paid to native species upstream of the Delta. An integrated research study on the Robinson reach and elsewhere on the Merced provides a unique opportunity to study the behavior and response of non-salmonid native species to habitat variables.

Methods

We propose a number of observational and manipulative studies related to the questions posed above. We are aware that any research that interferes with salmon in the Merced will be subject to regulatory oversight. In designing the studies every effort has been made to limit the invasiveness of the proposed methodology, and we will plan our proposed studies in consultation with the responsible permitting agencies.

Observational Research

1. Redd Site Selection

- Monitor movement of Chinook into and out of Robinson Reach using acoustic fish counting equipment and note timing and location of each redd as it is constructed. Monitoring of fish movement through the reach will allow us to assess which segment of the run contributes most to the local spawning population. Coordinate this work with the tributary-wide monitoring of spawning salmon distribution by CDFG.

- Radio-tag individual adult salmon entering the reach and monitor their behavior in the reach and as they take up residence or move upstream. Tagging fish from different segments of the run will define more precisely behavior within the reach and upstream, and will determine stream life in relation to migration timing and physical variables such as temperature. Tagged individuals moving through the reach will be located where they settle upstream and will be subjected to a lower level of monitoring.

- Map precise location of redds within Robinson Reach and upstream. These maps will be compared with maps of physical and chemical characteristics to assess habitat preferences and to compare measured values for Robinson Reach with published habitat preference curves.
- Observe spawning behavior and nest construction on selected redds by underwater video. These observations will allow analysis of behavior in relation to physical characteristics of redd locations within and outside of Robinson Reach. Of particular interest will be the behavior of females nesting on or off the humps engineered into the riffles within the reach.

2. Egg and Embryo Survival

- Monitor egg development in selected redds in and outside of Robinson Reach to assess development rate in relation to physical and chemical characteristics of interstitial water (flow, salinity, DO, TDS). Freeze-core samples will be removed twice from a selected number of redds at 200 and 400 degree days to compare development and survival within and without Robinson Reach. Samples will provide data on egg burial depth, substrate composition, development stage, embryo weight, and survival index. Additional sampling will be required to measure subgravel flow using either the dye injection or electronic technique.
- Assess the possibility of invertebrate or vertebrate predation on developing eggs by sampling benthic organisms within spawning riffles. Freeze-core samples will be used to search for predators of eggs and embryos at sites where Lenihan is studying the invertebrates and Dunne and Wydzga are studying the infiltration of fine sediment into the bed as it is controlled by the hydrodynamics and sediment supply of the restored reach.

3. Juvenile Habitat Use

- Monitor fry emergence and dispersal by means of upstream and downstream traps. Measure length, weight and degree of yolk absorption in migrating fry. The measurements will characterize the downstream dispersing fry in comparison with those residing within the reach.
- Monitor fry size and distribution within habitats of Robinson Reach and upstream by seining, minnow trapping, snorkeling, and underwater video. Particular emphasis will be on determining habitat choice in relation to depth, flow field, substrate, food, and cover. These data will be integrated with substrate and flow modeling and invertebrate sampling to model habitat preferences in relation to physics and food. By collaborating with CDFG we hope to be able to define juvenile distribution among reaches and the relative contribution of restored and unrestored reaches to juvenile production.
- Capture and tag individual fry within selected habitats to assess site fidelity and behavior in relation to conspecifics. Available tagging techniques include cold branding, vital dyes, latex injection, and tattooing. Fry behavior observations will be conducted by snorkeling and underwater video. Collaboration with vital dye and PIT tagging programs of CDFG will increase our ability to interpret and extrapolate from these studies.
- Identify nighttime habitats of fry and evaluate the relationship between day and night habitats. The technique for doing this remains to be worked out, so initially the study will involve exploration of technique. Elsewhere we have found that juveniles come into very

shallow, low velocity water near shore at night but there may also be other refuges and behavior may vary with age and size, and these may increase with in-channel structure..

- Monitor feeding rates of selected fry by snorkeling and/or underwater video at different times of day and in different habitats to assess foraging efficiency. Determine feeding habits and daily ration by analyzing stomach contents removed by gastric lavage.

4. Juvenile growth

- Select tagged individuals whose behavioral and movement histories are well resolved to analyze for growth patterns. The daily growth of individual fish can be reconstructed from microscopic analysis of the otoliths (ear bones), which lay down daily rings [Hobbs et al., 2004].

5. Integrated productivity

- Ensure that all parameters in the salmon model are being measured.

4. Non-salmonid species

- Monitor abundance, distribution and size of non-salmonid fishes by trapping, seining, snorkeling, and snorkeling. Habitat use by non-salmonids can be compared with physical and biological attributes to determine habitat preference curves. These can be compared with published data for other systems.

- Radio and/or floy tag selected individuals among the non-salmonids to obtain detailed information on movement patterns and daily routine.

- Determine diets and feeding rates of non-salmonids by gastric lavage. Particular attention will be paid to the behavior and distribution of benthic feeding fishes during spawning and egg incubation as they may be egg and embryo predators.

Experiments

1. Redd Site Selection

- Modify depth, substrate composition, and/or subgravel flow in selected locations to assess their effect on redd site selection. An experiment of this nature is already underway as riffle topography was designed with humps to provide preferred redd sites for Chinook, and the results are being monitored by Dr. Randy Mager of CDWR. Our own experiments will be informed by the observational data on redd site selection, and will test whether we can enhance or detract from the desirability of sites by specific kinds of manipulations.

2. Egg and Embryo Survival

- Plant egg baskets in areas of the reach having specific physical characteristics to determine development and survival of embryos under specific conditions. The nature and development of the physical characteristics will be studied simultaneously by A. Wydzga (see section A). Sites outside Robinson Reach may be used to increase the contrast in conditions.

- Raise eggs under different temperature and DO regimes to determine if development patterns of the Merced population are consistent with published information on the effects of temperature and oxygen concentration on development.

The results of these experiments will allow better tuning of population models that incorporate egg-to-fry survival as a discrete component. A goal is to elaborate and tune models such as that published by Jager et al. [1997] to more accurately represent the dynamics of chinook ecology in the Merced River and Robinson Reach.

3. Juvenile Habitat Use

- Alter local depth, flow, and substrate characteristics and food delivery to determine if juvenile use of a habitat can be enhanced or discouraged. The intent here is to test assumptions and preliminary predictions of models that derive habitat value from physical and biological attributes. These experiments will be informed by the observational data on habitat preferences and results of other studies that relate food and physical attributes to habitat choice in salmonids.

4. Non-salmonid species

- No experiments planned at this time

Model Development

The overarching objective of the entire study is to integrate information from measurement and modeling of the physical habitat, invertebrate abundance, and production of fish (particularly salmonids) to develop a model of habitat use and habitat value within the Merced and the Robinson Reach in particular. The models developed will eventually be transferable to other rivers. Several modeling approaches will be employed over the duration of the research:

- Using existing habitat models to assess and predict habitat value in advance of making biological measurements to generate predictions and help direct sampling design. We would use PHABSIM and various statistical models of habitat suitability and habitat value.

- Re-tuning existing models based on measurements made within the study (For example, improving PHABSIM predictions using locally derived habitat preference curves, and re-parameterizing statistical models with Merced-specific data).

- Developing new statistical models of various aspects of habitat use based on the data collected on the Merced.

- Developing dynamic energy budget models that reflect salmon biology, and using data from the experiments and the measurements of individual growth rates to estimate parameters of the models. These fitted models will allow us to relate patterns of growth among individuals to the measurements of both abiotic factors and the availability of invertebrate food that have been made in the locations where the fish were sampled. This will allow us to understand what factors influence the growth of fish and how these are related to the various habitats in the reach.

- Parameterizing (and modifying if needed) the Jager et al. [1997] model. Comparing the predictions of this model with the observed number of adults entering the reach and subsequent juveniles leaving the reach will allow us to determine whether our understanding of the conditions influencing salmon spawning and juvenile survival is complete. This model will also allow us to estimate the relative contributions of the various habitat types in the reach to salmon recruitment, which will inform future restoration projects.

- Developing a spatially explicit population model for the resident non-salmonid species, using data on movement of marked individuals as well as spatial data on biotic and abiotic factors along the reach. This model will be similar to that of Anderson et al. [2005], in which space is treated as one-dimensional and the fish movement and the population dynamics of both the fish and their invertebrate prey are modeled at each location. This will allow us to understand the role of the various habitat types, as well as their spatial configuration, in maintaining the health of the fish populations. This model will also allow us to predict the spatial extent of the response of a disturbance (such as an input of bed-material sediment) at a particular location [Anderson et al., 2005].

Products

We hope to produce three kinds of results from this research. The first is a more detailed assessment of how completely restructuring and re-scaling a river, such as the Robinson Reach restoration project, and other CALFED restoration projects, affects biological resources. These projects are extremely expensive and deserve a thorough evaluation of how they affect the mechanisms of fish production. The second is a better understanding of habitat use within the tributary by Chinook and other fish species. Improved understanding of habitat values for spawning, incubation and juvenile rearing will provide a firmer basis for future conservation and restoration projects throughout the Central Valley. Our research concentrated on the Robinson Reach will be augmented by lower intensity measurements outside the reach and by collaboration with CDFG in tributary-level assessment. The third kind of result will be a new generation of integrated "Physics-to-Fish" models that will improve the process of habitat evaluation and provide a better understanding of the dynamic relationships that tie fish ecology and behavior to managed physical habitat. We intend to take advantage of the special characteristics (simplicity, newness, gradually evolving complexity, and opportunity for experimentation) in the Robinson and neighboring reaches of the Merced to further this goal. The biggest advantage of the Merced project is the potential to integrate physical studies with biological responses in ways that have not been reported in the scientific literature.

D. RESTORATION OF FLOODPLAIN VEGETATION UNDER ALTERED FLOW REGIMES [Davis]

Description of the Topic

Understanding the relationship between floodplain revegetation, planting strategies, partially restored flow regime, and long-term vegetation dynamics is critical to successful restoration planning and design. It can suggest strategies for planting, controlling flow regimes and water table heights, and designing floodplain topography, as well as provide a risk-based expectation for the time scales for revegetation.

The floodplain of the Robinson Reach of the Merced River has undergone extensive rehabilitation at the scales of the site and river reach but the river still experiences reduced flows, flow variability, and sediment loads. Restoration of the floodplain has involved grading, planting, mycorrhizal inoculation, and irrigation in 6 management areas and an adaptive management program involving some experimentation and a monitoring program is underway [California Department of Water Resources 2003]. We propose a 3-year research program designed to complement these ongoing management experiments with additional observations, manipulative experiments and modeling of the processes of plant community assembly. Our interdisciplinary research will focus on elucidating the coupling of hydrologic and geomorphic processes to the development of floodplain vegetation under regulated flow. The program will be implemented in close consultation with agency staff and consultants to ensure that our experiments are compatible with site restoration goals and management activities.

Based on scientific research to date, we expect novel plant communities to develop in the different management areas of the study reach that retain some characteristics of the original riparian species assemblages and successional relations but exhibit very different species abundances, structure, spatial pattern and dynamics. Because of the strong coupling and feedbacks between abiotic and biotic components of the system, we also predict that plant community development from simple starting conditions to more complex biological communities will vary considerably depending on initial floodplain restoration and re-vegetation practices at both the site and river reach scales as they interact with the flow regime and sediment and channel that will be documented in component A of the integrated study.

Scientific Questions to be Addressed

Overarching question:

What degree of restoration of riparian plant communities is achievable under partial restoration of historic flow regimes, which may affect moisture conditions in the riparian root zone, sedimentation, and channel mobility?

Specific questions for analytical design:

1) *What is the relationship between flow regime, water-table elevations, and floodplain vegetation pattern and succession on restored river reaches experiencing reduced flow levels and variability?*
2) *How do initial plant community pattern, structure and composition influence restoration outcomes for floodplain plant communities? In particular, do restoration strategies initiate ecological patterns and processes that promote the assembly of resilient communities and long-term persistence of desired species?*
3) *How are species-specific patterns of tree establishment and growth affected by management actions to control exotic plant species?*

To address these questions we will conduct observational and manipulative experimental studies at the local scale. These studies will be coupled to the development of dynamic models of site, reach-, and catchment-scale processes to examine long-term consequences of alternative vegetation restoration and water management strategies. The research will be conducted in close consultation with California Department of Water Resources and the California Department of Fish and Game, the agencies responsible for the initial restoration design and post-project monitoring, to ensure that the research is compatible with restoration goals and constraints and takes maximum advantage of the existing restoration design, management and monitoring.

Background

The mature floodplain vegetation of the site is classified as Valley Foothill Riparian (VRI) habitat. Mature VRI forest has a canopy layer of some combination of white alder, cottonwood, California sycamore, valley oak, and one or more willow species, a subcanopy tree layer, an understorey shrub and liana layer, and an herbaceous layer consisting of sedges, rushes, grasses, and some forbs [Warner and Hendrix, 1984; Moyle et al., 1996; Harris, 1999].

We have fair understanding of the basic autecology of dominant floodplain tree species in relation to streamflow regime and fluvial geomorphology [e.g., Naiman and Decamps, 1997; Mahoney and Rood, 1998; Stromberg, 2001; Nilsson and Svedmark, 2002; Shafroth et al., 2002]. Patterns of tree establishment and growth reflect species-specific responses to the timing and magnitude of flood stage and the rate of water-table recession [Alpert et al., 1999; Amlin and

Rood, 2001; Amlin and Rood, 2002]. Flood disturbances and interactions between the floodplain topography and the water table maintain a mosaic of seral communities that vary with geomorphic position, which in the case of the initial study site has been simplified, but which is expected to become more complex topographically, sedimentologically, and hydrogeologically over time. Disturbance history, seed supply, local soil conditions and inter-specific competition cause actual community structure and composition to vary considerably from site to site. Observations of rivers where historical flow regimes have been partially restored (e.g., the Truckee River) indicate potentially rapid response of local riparian vegetation patterns to catchment-scale processes and highlight that floodplain community dynamics are governed by multiple scales of control [Wissmar and Beschta, 1998; Stromberg, 2001; Rood et al., 2003]

Research to guide restoration of floodplain vegetation has generally focused on the site scale and on practices to accelerate establishment and growth of desired tree species. These practices include grading, soil replenishment and site preparation, planting (seeds, seedlings and/or cuttings), soil amendments (mulch, fertilizer), and maintenance activities (e.g., weed control, pest control, irrigation). Such practices are expensive, labor-intensive and risky Rood et al. 2003) but they can achieve rapid re-vegetation Alpert et al. 1999). **A key question is whether such restoration practices initiate ecological patterns and processes that will promote the assembly of resilient communities and long-term persistence of desired species.** Because little long-term monitoring has been conducted on restored floodplains, we have poor understanding of the relationship between initial vegetation composition and structure and associated management actions undertaken early in the restoration process (such as weed control or irrigation), and the growth and development of more complex vegetation structure (with associated biotic and abiotic feedbacks) and long-term floodplain vegetation dynamics.

Methods

The proposed research will combine (a) observational research on historical and current vegetation and environmental conditions, (b) experimental manipulation of tree composition and density, and (c) mathematical modeling of floodplain tree populations and vegetation dynamics.

Observational Research

The goal of the observational research is to describe spatial and temporal patterns of floodplain vegetation dynamics in relation to hydrology, soil, and biotic factors. Eventually we will construct formal demographic models for the dominant tree species en route to predictive modeling of floodplain vegetation dynamics. To do this we must monitor species-, age- and size-specific rates of establishment, growth and mortality. This can be accomplished using a mixture of air photos and plot measurements.

We will make intensive measurements of vegetation colonization of the immediate riparian zone because it directly affects geomorphic processes of bank erosion, bar stabilization, and near-bank flow velocities in the channel. In turn, these factors are expected to alter the near-bank channel-bed morphology and thus the availability of shallow-water rearing habitat for juvenile fishes [Trush et al., 2000]. Aggressive invasion of the channel margins by strongly rooted woody plants is facilitated by reduced frequency of high flow velocities [Ligon et al., 1995], and may reinforce the bank and force the development of a rectangular cross section instead of an asymmetrical cross section that would provide a greater diversity of aquatic habitat conditions. We will monitor colonization and uprooting of woody plants along the channel margins.

Historical and modern air photos will be used to develop detailed maps of floodplain vegetation on the restored reach and along upstream and downstream reaches (ca. 1 km in each direction). We will also evaluate the use of imaging LIDAR to map and monitor 3-dimensional vegetation structure. The technique promises major efficiencies for vegetation monitoring. We will use a minimum mapping unit of ca. 0.05 ha. Modern vegetation attributes will include: general vegetation type (Sawyer/Keeler-Wolf System); tree canopy closure; canopy composition (cover values for individual tree species); shrub canopy closure; herbaceous canopy cover; and percent exposed ground. This level of information will require extensive ground survey. Using historical photos we will map tree, shrub and herb cover and, if possible, tree species composition and dominant weedy species. These maps will be used to examine spatial (landscape-level) ecological controls on vegetation development at the site.

Community composition and dynamics will be monitored on belt transects orthogonal to the channel reach. Vegetation monitoring is ongoing along 30m belt transects [CDWR, 2003]. We will augment this monitoring effort with added transects and additional vegetation attributes. The final size and spacing of these transects will be determined during initial field surveys and in consultation with other team members investigating hydrology and geomorphology of the study reach. The existing monitoring plan calls for vegetation sampling in April and June on an annual basis for at least ten years. Our design will expand the monitoring effort for the first three years to obtain more detailed descriptions of vegetation structure and composition, tree species density, recruitment, mortality and growth rates at the site. Soil texture, soil moisture in the vadose zone, and depth to water table at an existing set of wells will also be described and monitored.

Three years will only allow us to look at seedling and sapling stages on the study reach during this first phase of the study, so we will also have to rely on the published literature, archival photography, and age structure (tree ring) analysis of mature forests in adjacent reaches to reconstruct the expected demography of adult trees on the restored site over time. For dominant tree species we will monitor age-specific density and canopy height. Plant community data will be analyzed in relation to biotic and abiotic factors using canonical correspondence analysis (CCA) and species-specific direct gradient analysis. Tree demographic data will be synthesized in the form of species-specific, age-structured Leslie matrices and in more generalized stage-structured, community-specific Markov matrices. In combination with hydrological and geomorphic studies and repeat mapping of the floodplain, these analyses will allow us to describe space-time pathways that lead to patterns of tree survival and growth on different geomorphic surfaces of the floodplain. They will form the basis for predicting patterns of plant community structure that might be expected on other restored floodplains in the region, and this hypothesis can be tested in neighboring restored and relatively undisturbed river valleys.

Experimental Research

Restoration of floodplain vegetation at Robinson Reach has already been implemented with a novel experimental framework that includes experimental irrigation regimes, planting schemes and weed control in 6 management areas. Our experiments will nest inside these experiments in existing management areas. We will supplement ongoing monitoring efforts with more detailed biophysical measurements (e.g., vadose zone soil moisture profiles, soil macronutrients) and demographic data, and will manipulate local vegetation to gain a mechanistic understanding of the controls on floodplain vegetation development. Experimental results will be synthesized via ecological models that will ultimately assist in developing expectations for adaptive ecosystem management here and at similar sites through the CALFED solution area.

The details of our experimental design will be worked out in collaboration with CDWR scientists and collaborators responsible for the initial re-vegetation and subsequent monitoring of the study reach along with other members of our own research team. Here we propose two specific directions to enhance the existing experiment:

1. deliberate manipulation of plant densities within management units to examine the coupling between early successional vegetation structure and composition and longer term restoration outcomes, and
2. studies of soil moisture and plant water status across the range of environments and experimental zones to improve mechanistic understanding of the relationship between site hydrology and riparian community succession.

We hypothesize that the seasonal and stochastic patterns of moisture availability at sites within the floodplain will depend on: the generalized pattern of water-table elevations (driven by seasonal recharge outside of the floodplain, including irrigation on neighboring land), floodplain topography, textural variability of the aquifer, and local recharge (rainfall and overbank flooding). We will test the hypothesis that vegetation growth responds mainly to the first-order spatial pattern of moisture (dominated by distance from the channel) against the hypothesis that local variability dominates the revegetation pattern.

Species-specific survivorship and growth rates of the experimental tree populations will be monitored annually (June-July), along with vegetation structure and composition in the experimental plots. Soil texture and chemistry will be measured and soil moisture will be monitored to supplement water-table heights that are already measured. These data will be used to better understand community development and for comparing alternative restoration strategies. The data will also inform design and parameterization of a model of floodplain vegetation development, as described below.

To examine the relationship between initial conditions and vegetation development we suggest manipulating tree seed and seedling and cutting density in experimental 0.05 ha plots on different geomorphic surfaces. This will entail modifying the existing re-vegetation plantings (which are now comprised of regularly spaced willow cuttings, selective planting of oak seedlings, etc.) to create a factorial experiment that varies starting densities of the target species on different geomorphic surfaces. The potential for such manipulations will have to be negotiated with the local responsible agencies and landowner. Thus, we may alter our plans for these studies, but we have some specific ideas to propose.

The role of summer drought in limiting tree seedling and sapling establishment is well documented. Less well understood is the relationship between soil water and groundwater dynamics and tree growth and competitive interactions during early floodplain succession. The combination of vadose zone soil-moisture data and groundwater data from 35 existing wells that are monitored on a monthly or bi-monthly basis by the CDWR [2003] offers an unprecedented opportunity to examine species-specific changes in plant water relations during succession. To this end, in collaboration with ongoing studies of seedling establishment and water-table height, we will collect pre-dawn xylem pressure potential data from 6 woody species (planted at the site) at several dates between April and October. Thus, we will allow examine relationships among soil hydrology, local vegetation structure, species densities, physiology and growth on different geomorphic surfaces, under different irrigation regimes, and at different population densities.

Model Development

Our goal is to create a model of floodplain tree population dynamics that can ultimately be coupled to models of river hydrology (water stage regime and inundation frequency), geomorphology (sediment accumulation), and ecological interactions. We aim to simulate tree population dynamics in space and time using stand development models linked to spatially explicit models of floodplain disturbance and seed dispersal. This is an ambitious goal, however, and we will begin by using relatively simple state-transition models that simulate the spatial and temporal dynamics of discrete patch types (seral stages of a small number of major community types) on the floodplain landscape as a function of disturbance history, vegetation patch age, and geomorphic location. This approach is reviewed by [Urban et al., 1999] and has been successfully applied in a variety of vegetation types to investigate long-term vegetation dynamics under different disturbance regimes e.g., [Davis and Burrows, 1993; Urban et al., 1999]. The model will provide the means of coupling floodplain vegetation dynamics to flow regime (and associated floodplain disturbance regime) as well as restoration and management practices. Thus it will integrate findings from the observational and experimental components of the research.

Products

The research program is designed to help us understand and predict floodplain vegetation recovery and dynamics along restored river reaches under partially restored flow regimes. Our observational studies will establish a baseline for monitoring vegetation dynamics on the restored reach, quantify environmental controls on floodplain vegetation, and characterize both short- and mid-term vegetation dynamics in relation to the hydrological and geomorphological processes and conditions that are being restored. Our experimental studies will elucidate how biological complexity develops on restored floodplains and the relationship between initial ecological conditions and longer-term vegetation succession. We will also examine the interactions between the flow, sedimentation, and morphological conditions of the floodplain, revegetation, and the effects of the evolving riparian plant community on in-channel aquatic habitat. Modeling will be used to organize and integrate our findings, link floodplain vegetation to other components of the system, and explore long-term implications of hydrologic regimes and re-vegetation strategies.

The research is designed as one component of the larger multi-disciplinary effort to understand the coupling of abiotic and biotic processes in rivers and their floodplains. In addition to providing an understanding of how hydrology and geomorphic processes affect plant communities, our detailed studies of how the dynamic riparian zone plant communities develop will directly aid in geomorphic studies of the evolution of the channel boundary, bank erosion, and the near-bank channel morphology that is expected to provide shallow-water rearing habitat for juvenile fishes (Trush et al., 2000). As the floodplain vegetation densifies, we expect that it will alter overbank flow velocities and induced fine sediment accumulation, which will be mapped if and when it occurs. Findings from this research component will improve estimation of trends to be expected in managed floodplain vegetation communities in the CALFED region and in other Mediterranean-climate systems in California and elsewhere.

FEASIBILITY, TIMING, AND MANAGEMENT OF THE STUDY

Sites within the Merced River Salmon Habitat Enhancement Project offer an excellent opportunity for studying the physical and biotic processes that are altered by river restoration. The site involves a river of significant size, with a managed flow regime and simple geometry where detailed physical and biological measurements can be made under planned conditions. The site is easily accessible with instruments and machinery. The initial state was designed after thorough interdisciplinary study, using modern conceptual models of river restoration, it has been thoroughly documented from the outset, and a regular monitoring program continues. Change is currently slow, so that the modest changes in the first four post-construction years can be documented in detail, and the designed flow processes, bed state, and related biological processes can be thoroughly documented in surveys of associations and by experimental manipulation. Measurements can be made under comfortable conditions and at times that are convenient and reliably anticipated. Thus, we expect to gather large amounts of data in three years.

It is also possible to envision conducting a wide range of experiments at the site to increase the state of learning about how river restoration affects biological resources. Although we do not yet know which experiments would be acceptable to the agencies responsible for river management, we have many ideas to propose. For example, sediment could be supplied to the reach from convenient stockpiles, after we have made a thorough empirical and model study of the response to be expected from such an intervention. Managed flow releases from New Exchequer Dam could also be planned in a similar manner and used for a variety of studies. Smaller experiments could be designed by locally altering the bed condition, the bank geometry, and in-channel physical structure. In each case, our own team and other scientists could mount intensive measurement campaigns, obtaining unprecedented data sets. Each experiment could be carefully planned with a modeling study based on field measurements. These convenient experiments could increase the rate of learning about responses to river restoration, and indicate approaches that could be replicated in other rivers.

The team is closely integrated, with only one member (Healey) living at considerable distance from the site, but able to travel to the Merced for lengthy sampling campaigns. Of the others, four are colleagues in the same building, and they already collaborate in teaching and supervision of graduate students. Faulkenberry designed and built the Merced restoration projects, and two of the graduate students on this project have worked part-time for him under Dunne's supervision. All of the co-PIs are experienced at running or analyzing data from quantitative field projects on rivers, floodplains, or estuaries, among their other projects. They participate in the collection of the data they analyze. However, most of the work will be done by postdoctoral researchers and three graduate students, some of whom would live near the river, and all of whom need to collect significant data sets and publish outstanding results in the scientific literature, which insures that data will be analyzed promptly. All personnel will share an interest in conducting research that is directly relevant to river restoration based on fundamental environmental science. **The focus of the project, in other words, will be on river restoration**. In order to accomplish this goal there is a profound realization of the need for fully integrated studies of physics and biology at several scales and levels of resolution.

We have also given some thought to disseminating our results effectively to people involved in the profession of river restoration. In addition to publications in the scientific literature, and presentations at the CALFED Science Conference, we have been told by agency personnel that small workshops would be an effective means of communication and we are eager to participate in such events. We would also participate in smaller group field meetings and planning sessions with agency personnel conducting joint field studies or data analyses.

PROJECT JUSTIFICATION

The long-term prospects for river restoration hinge upon the ability to design and implement projects that achieve their ecological objectives in a sustainable, economically feasible manner. We will develop information on how physical and biological processes adjust over time to river restoration. The results will be directly relevant to the design and maintenance of restored rivers in the region with its particular constraints on design and operation. The questions addressed were chosen after lengthy and wide-ranging consultations between the PIs and specialists in river restoration and ecosystem management, as well as our reading of the literature and our experience during reviewing and consulting activities as well as active engagement in experimental field research for ecosystem conservation. Each of the PIs has experience with applied conservation, and has interacted with professionals in various fields to design ways of learning adaptively from the accumulation of experience during management actions. We also intend to take advantage of the opportunity for experimental, interdisciplinary studies at this site to generate fundamental ecological knowledge that will be useful for a wide range of conservation actions. The opportunity for experiments at this initially simple site, and for comparisons with more complex neighboring sites that have received other treatments or that remain un-restored will be pursued in cooperation with agencies as knowledge accumulates from this project.

SCIENTIFIC RESULTS FROM PREVIOUS CALFED FUNDING TO DUNNE

T. Dunne and M.B.Singer received a grant from the CALFED Science Program entitled "Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology" The grant extends from 2002 to 2005, and is funded at $390,252.

To date we have produced the following publications

1.Singer, M.B. and T. Dunne; Identifying eroding and depositional reaches of valley by analysis of suspended sediment transport in the Sacramento River, California. Water Resources Research, 37(12):3371-3382. 2001

2.Singer, M.B. and T. Dunne; Modeling decadal bed-material sediment flux based on stochastic hydrology. Water Resources Research, 40, W03302, doi: 10.1029/2003WR002723. 2004

3.Singer, M.B. and T. Dunne; An empirical-stochastic, event-based program for simulating inflow from a tributary network: Framework and application to the Sacramento River basin, California. Water Resources Research, 40, W07506, doi:10.1029/2003WR002725. 2004

4. Singer, M.B. and R.A. Aalto; Event-based sedimentation and scour in flood bypasses: A case study from the 1964 flood in the Sacramento Valley, California. Submitted to journal.

5. Singer, M.B.; Influence of major dams on hydrographs through a river network. Submitted to journal

6. Constantine, C.R., T. Dunne, M.B. Singer. Submitted to journal.

7 .Singer, M.B. and T. Dunne; Modeling the decadal influence of river rehabilitation scenarios on flow and sediment transport in large, lowland river basins. In Preparation

8. Dunne, T. *River Restoration as a Challenge to Hydrological Science*, Invited Langbein Lecture at Nice, France and San Francisco Meetings, Amer. Geophysical Union Powerpoint presentation posted on AGU website.(www.agu.org).

We have also presented talks with published abstracts at 9 conferences in California (two at CALFED Science Conference), nationally and internationally. Other papers are in preparation. We have also participated in many workshops and informal meetings with agency and university scientists working on CALFED projects.

The project continues with coring of the floodplains, flood basins, and flood bypasses of the Sacramento River. Many cores have been collected and are undergoing Lead-210 analysis to measure sediment accumulation rates over the past century. We plan at least five more papers in the international literature and a summary document describing the management implications of flow alteration, sediment augmentation, and setting back levees on the transport and accumulation of bed material and overbank sediment.

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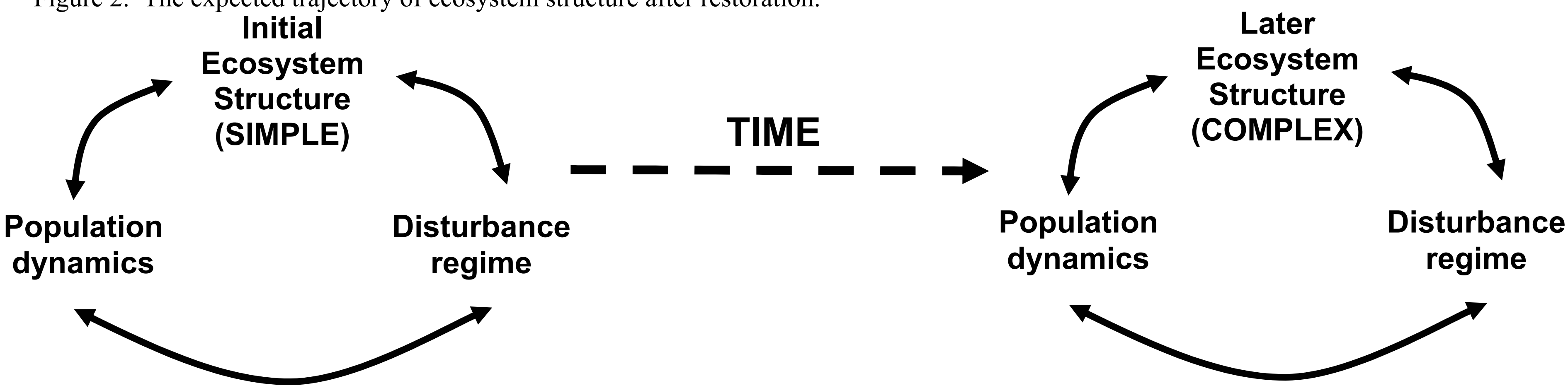
Figure 1. The Robinson Reach immediately after construction in 2001.

Figure 2. The expected trajectory of ecosystem structure after restoration.



STATE OF CALIFORNIA – THE RESOURCES AGENCY
ARNOLD SCHWARZENEGGER, Governor

DEPARTMENT OF WATER RESOURCES
DIVISION OF ENVIRONMENTAL SERVICES
3251 S STREET
SACRAMENTO, CA 95816-7017

January 5, 2005

Dr. Thomas Dunne
Donald Bren School of Environmental
Science and Management
University of California, Santa Barbara
3510 Bren Hall
Santa Barbara, California 93106-5131

Dear Dr. Dunne:

I am writing in reference to the usefulness of information to be collected through an integrated study on the Merced River Salmon Habitat Enhancement Project (MRSHEP). I understand that this study will investigate how abiotic and biotic processes, and their interactions, sustain habitat characteristics and functions in river channels and floodplains. In particular, the development of innovative modeling and monitoring techniques will help to standardize and advance the science of river restoration. The multidisciplinary team will provide an excellent forum for developing the science greatly needed for the advancement of river restoration on the San Joaquin River system.

With the focus of the study on the MRSHEP Robinson Reach, the results will have direct application to our adaptive management of this project and implementation of future MRSHEP phases. The information developed will also be useful for other river restoration and salmonid habitat projects being undertaken by the Four Pumps Agreement and others in the San Joaquin Basin.

If you have any questions or need further information, please contact me at (916) 227-7536.

Sincerely,

Stephani A. Spaar
Staff Environmental Scientist
Delta Pumping Plant Fish Protection
(Four Pumps) Agreement

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Stockton Fish and Wildlife Office
4001 North Wilson Way, Stockton, CA 95205-2486
209-946-6400 FAX: 209-946-6355

January 4, 2005

Dr. Thomas Dunne, Professor
Donald Bren School of Environmental Science and Management
University of California, Santa Barbara
Santa Barbara, California

Re: Support Letter for Proposed Interdisciplinary Study on the Merced River

I have read your concept proposal entitled "How Abiotic Processes, and their Interactions Sustain Habitat Characteristics and Functions in River Channels and Floodplains: An Investigation of the Response of a Gravel-Bed Reach of the Merced River to Restoration", and agree that an investigation of this magnitude can provide much needed quantitative data that is directly useful for the design and evaluation of future river restoration projects. Establishing a quantitative link between restored aquatic and riparian habitats and the biological response is essential for effectively designing and predicting the benefits of future restoration projects. However, we recommend that you expand your studies to compare different approaches of restoring anadromous salmonid habitat in the San Joaquin River basin and to evaluate the biological responses at the population level.

All of the tributaries to the San Joaquin River have substantially altered hydrographs and severe channel degradation from gravel excavation. And yet, different restoration strategies are being proposed for each of these rivers. A study that would compare the biological and geomorphological responses to these different strategies over time would provide the greatest opportunity to maximize the effectiveness of future projects. There are also opportunities to employ different restoration strategies in the Merced River to further enhance our learning opportunities.

The Anadromous Fish Restoration Program also needs to know whether restoration projects are contributing to our doubling goal. In addition to evaluating fish use of project sites, we should also monitor the total number of juvenile salmonids produced per spawner for each river over time. To accomplish this on both the Merced and Tuolumne rivers, the screw trapping needs to be expanded and secure funding may be needed to continue the escapement surveys in fall 2005. Carl and I will help to either expand your project or develop new projects to incorporate this monitoring.

If you have any questions please contact me at (209) 946-6400 x 315 or (209) 403-1457 (cell).

Sincerely,

Cesar Cadena Blanco, Ph.D.
Fishery Biologist, Stockton FRO

cc: Russell Bellmer, John Icanberry & Carl Mesick - USFWS Stockton FRO

THOMAS DUNNE: CURRICULUM VITAE

Professor, Donald Bren School of Environmental Science and Management, and Department of Geological Sciences, 3510 Bren Hall, University of California, Santa Barbara, CA 93106.

EDUCATION B.A. 1964 Cambridge Univ., UK; Ph.D. 1969 Johns Hopkins University, (Geography).

HONORS Fulbright Scholar, 1964; Robert E. Horton Award, American Geophysical Union, 1987; National Academy of Sciences, 1988; Fellow, American Geophysical Union, 1989; Guggenheim Fellowship, 1989; American Academy of Arts and Sciences, 1993; Fellow, California Academy of Sciences, 1996; National Research Council Wolman Distinguished Lecturer, 1997; National Academy of Sciences Warren Prize for Fluviatile Geology, 1998; Bren School Distinguished Teaching Award, 2002; American Geophysical Union Langbein Lecturer, 2003; Geological Society of America Easterbrook Distinguished Scientist Award.

CURRENT RESEARCH INTERESTS
Field and theoretical studies of drainage basin and hillslope evolution
Hydrology, sediment transport, and sedimentation in river channels and floodplains
Field studies and modeling of river-basin sediment budgets.

Thomas Dunne is a Professor of Environmental Science and Management, and of Geological Sciences at the University of California Santa Barbara. He conducts field and theoretical studies of drainage-basin, hillslope, and fluvial geomorphology, and in the application of hydrology, sediment transport, and geomorphology to landscape management and hazard analysis.

While working for the USDA Agricultural Research Service (1966-1969) and McGill University (1971-1973), he conducted research on the effects of topography, soil characteristics, and vegetation on runoff processes under rainfall and snowmelt in Vermont and Canada. While teaching at the University of Nairobi, Kenya (1969-1971), he initiated an enduring research interest in African environments, including experimental studies of runoff and erosion processes, and statistical studies and field surveys of the effects of land use on hillslope erosion and river-basin sediment yields. He also conducted occasional studies of reservoir sedimentation, water quality, and erosion due to charcoal production and grazing. This work was supported by the Rockefeller, Guggenheim, and Beijer Foundations, the United Nations, National Science Foundation, and Kenya government agencies between 1969 and 1991.

While teaching in the Department of Geological Sciences at the University of Washington (1973-1995), he studied landsliding and debris flows; drainage-basin sediment budgets in natural and managed forests; tephra erosion and debris-flow sedimentation on active volcanoes; and sediment transport and channel morphology in sand-bed and gravel-bed river channels. He also conducted several studies related to resource management, such as the impacts of gravel harvesting on river-channel sedimentation and morphology; impacts of timber harvest on erosion and sedimentation; and effects of flow diversion and reservoir management on sedimentation. The work was funded by NSF, state agencies (Dept of Ecology and of Natural Resources), and federal agencies (USFS, USGS, FEMA).

He now studies hydrology, sediment transport, and floodplain sedimentation in the mainstem Amazon River of Brazil and in the Andes Range and adjacent floodplains of eastern Bolivia. His work, funded by NSF and NASA. In California, he and his students study sediment transport, channel change and oxbow lake sedimentation along the Sacramento River and its floodplain and fine-sediment intrusion into gravel stream beds.

RELEVANT PUBLICATIONS

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R. E. Beighley, T. Dunne, and J. M. Melack, Understanding and modeling basin hydrology: Interpreting the hydrogeological signature, **Hydrological Processes** (in press)

BIOGRAPHICAL SKETCH

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Education

B.A.	1975	Biology	Williams College
Ph.D.	1982	Geography and Environmental Engineering	The Johns Hopkins University

Professional Experience

1995-1998:	Deputy Director, National Center for Ecological Analysis and Synthesis, UCSB
1996-present:	Professor, Donald Bren School of Environmental Science and Management, UCSB
1994-present:	Professor, Department of Geography, UC Santa Barbara.
1989-1994:	Associate Professor, Department of Geography, UC Santa Barbara.
1983-1989:	Assistant Professor, Department of Geography, UC Santa Barbara.

Research Interests

Landscape ecology, plant ecology, quantitative biogeography, vegetation remote sensing, ecological applications of remote sensing and geographic information systems, conservation planning

Professional Societies

Ecological Society of America, International Association for Vegetation Science, Society for Conservation Biology

Selected Recent Professional Activity

Board of Editors, *Conservation Biology*, 1993-1999
Principal Investigator, California Gap Analysis Project, 1990-1998
National Research Council Committee on the Formation of the National Biological Survey, 1993
Science Team, U.S. Forest Service Sierra Nevada Ecosystem Project, 1993-1996
National Research Council Forum on Biodiversity Steering Committee, 1995-1997
Board of Editors, *Geographical and Environmental Modeling*, 1996-2002
National Steering Committee, USGS-BRD Gap Analysis Program, 1998-2002
Steering Committee, USGCRP California Regional Climate Change Workshop, 1997-1998
Board of Editors, *Ecology*, 1999-2003
National Research Council Committee on Restoration of the Greater Everglades Ecosystem, since 1999
Board of Trustees, The Nature Conservancy of California, since 2004

Recent Research Sponsors

Environmental Protection Agency, National Science Foundation, USDA Forest Service, The Nature Conservancy, USGS Biological Resources Division, World Bank, Doris Duke Foundation, The Resources Agency of California, County of Santa Barbara, David and Lucile Packard Foundation

Awards

Fellow, Aldo Leopold Leadership Program, 2001

Graduate Advisees and Postdoctoral Scholars during the past five years:

Ph.D.	**Postdoctoral Scholar**
Day, John	Tyler, Claudia
Taylor, Robert	Seo, Chang-wan
Jennings, Michael	
Richard Walker	
Christopher Pyke	

Doctoral Advisor: Grace S. Brush

Selected Relevant Publications

1987 Michaelsen, J., L. Haston and **F. W. Davis**. 400 years of Central California precipitation variability reconstructed from new tree-ring chronologies. *Water Resources Bulletin* 23:809-818.

1988 Borchert, M., **F. W. Davis**, J. Michaelsen and L. Oyler. Interactions of factors affecting seedling recruitment of blue oak (*Quercus douglasii*) in California. **Ecology** *70*:389-404.

1989 **Davis, F. W.**, M. Borchert and D. Odion. Establishment of microscale vegetation pattern in maritime chaparral after fire. **Vegetatio** 84:53-67.

1990 **Davis, F. W.** and S. Goetz. Modeling vegetation pattern using digital terrain data. **Landscape Ecology 4**: 69-80.

1991 Callaway, R.M. and **F.W. Davis**. Vegetation dynamics, fire and the physical environment in central California. **Ecology 74**: 1567-1578.

1992 **Davis, F. W**., D. S. Schimel, M. Friedl, R. Dubayah, T. G. F. Kittel and J. Dozier. Covariance of biophysical data with digital topographic and landuse maps over the FIFE site. *Journal of Geophysical Research 97(D17)*: 19,009-19,021.

1994 **Davis, F. W.** and D. A. Burrows. Spatial simulation of fire regime in mediterranean-climate landscapes. Pages 117-139 in, *The Role of Fire in Mediterranean-Type Ecosystems*, edited by M. C. Talens, W. C. Oechel and J. M. Moreno. Springer-Verlag, New York.

1995 **Davis, F. W**., P. A. Stine and D. M. Stoms. Remote sensing and GIS applied to phytogeographic analysis and conservation planning in southwestern California. **Journal of Vegetation Science** 5: 743-756.

1998 Callaway, R. M. and **F. W. Davis**. Recruitment of *Quercus agrifolia* on central California landscapes. *Journal of Vegetation Science* 9: 647-656.

2000 **Davis, F. W**. and D. Roberts. Stand structure in terrestrial ecosystems. Pp. 7-30 in, *Methods in Ecosystem Science* (O. E. Sala, R. B. Jackson, H. A. Mooney, R. W. Howarth, eds.), Springer, New York.

2000 Odion, D. C. and **F. W. Davis**. Fire, soil heating, and the formation of vegetation patterns in chaparral. **Ecological Monographs** 70: 149–169.

2001 Scott, J.M., **F. W. Davis**, G. McGhie, C. Groves. Nature reserves: do they capture the full range of America's biological diversity? **Ecological Applications** 11: 9999 – 1004.

2002 V. L. Sork, **F. W. Davis**, P. Smouse, V. Apsit, R. Dyer, J. Fernandez, W. Kuhn. Pollen movement in declining populations of California valley oak, Quercus lobata: Where have all the fathers gone? **Molecular Ecology** 11: 1657-1668.

MICHAEL C. HEALEY

Curriculum Vitae

Born: 1942, Prince Rupert, BC, Canadian Citizen

Address: 201-3784 West 16th
Vancouver, BC, V6R 3C4

Education:

BSc, Zoology, UBC, 1964
MSc, Zoology, UBC, 1966
PhD, Natural History, Aberdeen, Scotland, 1969

Employment History:

Postdoctoral Fellow, Pacific Biological Station, Nanaimo, BC, 1969-70.
Research Scientist and Program Leader, Northern Fish Populations, Freshwater Institute, Winnipeg, MB, 1970-74
Research Scientist and Program Leader, Juvenile Salmon Ecology, Pacific Biological Station, Nanaimo, BC, 1974-90.
Director of the Westwater Research Centre and Professor of Oceanography, UBC, Vancouver, BC, 1990-95.
Professor in Resources and Environment, Fisheries Centre and Department of Earth and Ocean Sciences, UBC, Vancouver, BC, 1996-present.

Professional Leaves:

Senior Fellow in Marine Policy, Woods Hole Oceanographic Institution, Woods Hole, MA, 1982-83.
Visiting Scientist, UBC, Zoology, Vancouver, BC, 1988-89.
Visiting Research Professor, Political Science and Coastal Resources Center, Univ. of Rhode Island, Kingston, RI, 1995-96.
Visiting Research Professor, Political Science, Univ. of Rhode Island, Kingston, RI, 2002-03.

Major Research Projects Presently Underway or Recently Completed:

Energetic Costs of Upstream Migration and Spawning in Pacific Salmon in Relation to Flow and Temperature and Disease (2002-2006). The study is funded under an NSERC strategic grant to Healey, Hinch, and Farrell. The project has received continuous funding from the Natural Sciences and Engineering Research Council in three successive large grants (1993-2006).

Analysis of Interactions between Cultured and Wild Salmonids in BC and the Risks to Wild Populations of Culture and Aquaculture Programs (2000-2003). This study funded under a Network of Centres of Excellence project entitled “AquaNet”. Research in this network has 3 foci, aquaculture production technology, socio-economic implications of aquaculture and environmental implications of aquaculture. With funding under the network, I and my students investigated competition and predator-prey interactions between cultured and wild salmon and modeling the risks to wild stocks from expansion of hatchery and aquaculture programs.

Habitat Requirements and Habitat Restoration/Conservation for Endangered Nooksack Dace and Salish Suckers in the Lower Fraser Valley. **A** 5-year study of distribution, habitat use, habitat requirements, habitat restoration and habitat conservation to ensure survival of two endangered fish species in streams of the lower Fraser River valley. Funded by the BC Habitat Conservation Trust Fund, the World Wildlife Fund, and the UBC Hampton Fund.

Recent Experience as Advisor and/or Consultant:

1) Member, science advisory committee, Northern River Basins Study, AB, 1992-96.
2) External Advisor, Water Management Branch, California Dept. of Fish and Game, Sacramento, CA, 1992, 1993, 1996, on research to conserve chinook salmon in the Sacramento and San Joaquin Rivers.
3) Special Advisor, Yukon Electric Company Ltd., 1993-1996, on environmental impact assessment of the Aishihik Lake hydro development.
4) Chair, Royal Society Committee to Evaluate Aquatic Science in Canada, 1994-95.
5) Special Advisor, Montana Dept. Fish and Game, US Biological Service and Federated Kootenai-Salish tribes, 1997, on prospects for conservation of bull trout in Flathead Lake.
6) Special Advisor, CALFED Bay-Delta program, California, 1998, on strategic plan to restore the ecosystems of the Sacramento-San Joaquin Delta and upper San Francisco Bay.
7) Member of Team of Experts convened by the Pacific Salmon Foundation to draft a habitat management strategy for salmon in British Columbia, 1998.
8) Member, Ecosystem Restoration Program, Science Advisory Board, CALFED Bay-Delta Program, California, 1999-present, on adaptive management and ecosystem management in ecological restoration of the Sacramento-San Joaquin delta and San Francisco Bay.
9) Member, expert group, NAFTA-CEC, 1999-2000, preparation of factual record concerning DFO enforcement of Fishery Act against BC Hydro.
10) American Fisheries Society delegate to Taiwan as an advisor on conservation of the endangered Formosa Landlocked Salmon, April, 2000.
11) Member, Board of Directors, Canadian Water Network (April 2001-present) (This is a federally funded, national program to study water supply and water quality in Canada).

Selected Recent Publications, 1999-2004:

2004 Cooke, S.J., S.G. Hinch, A.P. Farrell, M.F. Lapointe, S.R.M. Jones, J.S. Macdonald, D.A. Patterson, M.C. Healey, and G. Van Der Kraak. Abnormal migration timing and high en route mortality of sockeye salmon in the Fraser River, British Columbia. Fisheries 29:22-33.

2004 Crossin, G.T., S.G. Hinch, A.P. Farrell, M.P. Whelly, and M.C. Healey. Pink salmon (Oncorhynchus gorbuscha) migratory energetics: response to migratory difficulty and comparisons with sockeye (O. nerka). Can. J. Zool. **81**, 1986-1995.

2003 Healey, M.C., R. Lake, and S.G. Hinch. Energy expenditures during reproduction by sockeye salmon (Oncorhynchus nerka). Behaviour 140:161-182.

2003 Pearson, M, and M.C. Healey. Life History Characteristics of the Endangered Salish Sucker (*Catostomus sp.*) and their Implications for Management. *Copeia* 2003(4):759-768.

2003. Lee, C.G., Farrell, A.P., Lotto, A., MacNutt, M.J., Hinch, S.G., and Healey, M.C. The effect of temperature on swimming performance and oxygen consumption in adult sockeye (Oncorhynchus nerka) and coho (O. kisutch) salmon stocks. *Journal of Experimental Biology*206:3239-3251.

2002 Standen, E.M., S.G. Hinch, M.C. Healey and A.P. Farrell. Energetic costs of migration through the Fraser River canyon, British Columbia, in adult pink (*Oncorhynchus gorbuscha*) and sockeye (*O. nerka*) salmon as assessed by EMG telemetry. *Can. J. Fish. Aquat. Sci.* 59:1809-1818

2001 Healey, M.C. Patterns of reproductive investment by stream- and ocean-type chinook salmon (Oncorhynchus tshawytscha). *Journal of Fish Biology* 58:1545-1556.

2001 Healey, M.C., P. Kline, and C-F Tsai. Saving the endangered Formosa landlocked salmon.*Fisheries* 26:6-13.

2000 Healey, M.C., et al. Computer simulations of the effects of the Sitka eddy on the migration of sockeye salmon returning to British Columbia. *Fisheries Oceanography*. 9:271-281.

2000 Hennessey, T and M. Healey. Ludwig's ratchet and the collapse of New England groundfish stocks. *Coastal Management*. 28:187-213.

2000 Healey, M.C. Pacific salmon migrations in a dynamic ocean. p 29-61 In: P. Harrison and T. Parsons (ed.), Fisheries Oceanography, Blackwell, Oxford.

1999 Reinhardt, U.G., and M. C. Healey. Season- and size-dependent risk taking in juvenile coho salmon: experimental evaluation of asset protection. *Animal Behaviour* 57:923-933.

1999 Giannico, G. and M.C. Healey. Ideal free distribution theory as a tool to examine juvenile coho habitat choice under different conditions of food abundance and cover. *Canadian Journal of Fisheries and Aquatic Sciences* 56:2362-2373.

Bruce Edward Kendall

Education

1986	B.A.	Physics	Williams College
1996	Ph.D.	Ecology & Evolutionary Biology (W.M. Schaffer, advisor)	University of Arizona

Teaching Experience

Graduate classes in:

- Applied statistics and data analysis for environmental science and management
- Applied ecology (broad overview for students in Environmental Science & Management)
- Applied population biology (focus on population viability analysis)

Graduate seminars in:

- Invasion biology
- Ecosystem management
- Ecotoxicology
- Fisheries biology

Employment History

1996-1998	Postdoctoral Associate	National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara
1998-2004	Assistant Professor	Donald Bren School of Environmental Science and Management, University of California, Santa Barbara
2004-present	Associate Professor	Donald Bren School of Environmental Science and Management, University of California, Santa Barbara

Professional Activities

Judge for Murray F. Buell & E. Lucy Braun Awards (Ecological Society of America's awards for outstanding student oral and poster presentations at the ESA annual meeting), 6 years.

Organized symposium on "Intersection of diverse perspectives: results from creative collaborations in ecology" for Ecological Society of America annual meeting, 1998.

Member of the Science Panel for the Marine Reserves Working Group at the Channel Islands National Marine Sanctuary, 2000-01.

Member of Equid Specialist Group of the IUCN Species Survival Commission, 2002-present.

Judge for Lotka-Volterra Awards (Ecological Society of America's awards for outstanding student oral and poster presentations in the area of theoretical ecology at the ESA annual meeting), 2003.

Judge for Pielou Award (Ecological Society of America's awards for outstanding student oral and poster presentations in the area of statistical ecology at the ESA annual meeting), 2003.

Member of Academic Program Review Committee, Dept. of Ecology and Evolutionary Biology, University of Arizona, 2003.

Participant in scientific workshop for NRC panel on The Effects of Noise on Marine Mammals, 2004.

Associate editor for *Ecology* and *Ecological Monographs*, 2005-present.

Honors and Awards

University Postdoctoral Fellowship, University of Calgary (declined).

Postdoctoral Fellowship, National Center for Ecological Analysis and Synthesis (1996-1998).

Graduate Fellowship, Biomathematics and Dynamics Initiative, University of Arizona (1995).

Graduate Fellowship, Research Training Grant 'The Analysis of Biological Diversification,' University of Arizona (1994).

Graduate College Fellowship, University of Arizona (1989-1990).

Grants Received

D.A. Siegel, B.E. Kendall, R.R. Warner, S.D. Gaines, and C. Costello. 2003-2008. Disparate Scales of Process and Nearshore Fishery Management (NSF: $1,995,951).

R. Nisbet, A. Brooks, B. Kendall, P. Holden, K. Lafferty, E. Muller, C. Paige, and A. Stewart-Oaten. 2001-2006. Western Center for Estuarine Ecosystem Indicator Research: Ecological Indicators (USEPA: $1,880,000).

D.A. Siegel and B.E. Kendall. 2001-2004. Marine protected area design and monitoring using satellite data: a prototype study in the Channel Islands National Marine Sanctuary (NOAA: $320,000).

B. Kendall and G. Fox. 2001-2005. Individual variability, environmental stressors, and sampling uncertainty in wildlife risk assessment (USEPA: $427,000).

C. Costello and B. Kendall. 2001-2003. On the preservation of transboundary, non-harvested species (Institute for Global Conflict and Cooperation: $15,000).

B.E. Kendall and B.G. Bierwagen. 2002-2004. Dissertation research: Ecological and evolutionary effects of land use changes on butterflies (NSF: $8,000).

B.E. Kendall and C. McAusland. 2002-2003. Assessment of chemical and non-chemical stressors on fall-run Chinook salmon (California EPA: $18,000).

Refereed Publications (past 4 years)

Kendall, B. E. 2001. Cycles, chaos, and noise in predator-prey dynamics. *Chaos, Solitons & Fractals* **12:** 321-332.

Ellner, S. P., E. McCauley, B. E. Kendall, C. J. Briggs, P. R. Hosseini, S. N. Wood, A. Janssen, M. W. Sabelis, P. Turchin, R. M. Nisbet, and W. W. Murdoch. 2001. Habitat structure and population persistence in an experimental community. *Nature* **412:** 538-543.

Kendall, B.E., and G.A. Fox. 2002. Variation among individuals and reduced demographic stochasticity. *Conservation Biology* **16**: 109-116.

Fox, G.A., and B.E. Kendall. 2002. Demographic stochasticity and the variance reduction effect. *Ecology* **83**: 1928-1934.

Murdoch, W.W., B.E. Kendall, R.M. Nisbet, C.J. Briggs, E. McCauley, and R. Bolser. 2002. Single-species models for many-species food webs. *Nature* **417**: 541-543.

Murdoch, W. W., C. J. Briggs, R. M. Nisbet, B. E. Kendall, and E. McCauley. 2003. Natural enemy specialization and the period of population cycles: Reply. *Ecology Letters* **6:** 384-387.

Turchin, P., S. N. Wood, S. P. Ellner, B. E. Kendall, W. W. Murdoch, A. Fischlin, J. Casas, E. McCauley, and C. J. Briggs. 2003 Dynamical effects of plant quality and parasitism on population cycles of larch budmoth. *Ecology* **84:** 1207-1214.

Seabloom, E. W., E. T. Borer, V. L. Boucher, R. S. Burton, K. L. Cottingham, L. Goldwasser, W. K. Gram, B. E. Kendall, and F. Micheli. 2003. Competition, seed limitation, disturbance, and reestablishment of California native annual forbs. *Ecological Applications* **13:** 575-592.

Kendall, B. E., and G. A. Fox. 2003. Unstructured individual variation and demographic stochasticity. *Conservation Biology* **17:** 1170-1172.

Gram, W. K., E. T. Borer, K. L. Cottingham, E. W. Seabloom, V. L. Boucher, B. E. Kendall, L. Goldwasser, F. Micheli, and R. S. Burton. 2004. Conservation and restoration of native plants in California serpentine grasslands. *Plant Ecology* **172:** 159–171.

Armsworth, P. R., B. E. Kendall, and F. W. Davis. 2004. An Introduction to Biodiversity Concepts for Environmental Economists. *Resource & Energy Economics* **26:** 115-136.

Fujiwara, M., B. E. Kendall, and R. M. Nisbet. 2004. Growth autocorrelation and animal size variation. *Ecology Letters* **7:** 106-113.

Fujiwara, M., B. E. Kendall, R. M. Nisbet, and W. A. Bennett. Analysis of size trajectory data using an energetic-based growth model. In press, *Ecology*.

Kendall, B. E, S. P. Ellner, E. McCauley, S. N. Wood, C. J. Briggs, W. W. Murdoch, and P. Turchin. Population cycles in the pine looper moth (*Bupalus piniarius*): dynamical tests of mechanistic hypotheses. In press, *Ecological Monographs*.

CURRICULUM VITAE
Hunter Lenihan

Assistant Professor
Bren School of Environmental Science and Management
University of California, Santa Barbara
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Cell phone: (805) 570-0843

Education
1996 Doctor of Philosophy, Marine Sciences, University of North Carolina at Chapel Hill
1994 Master of Science, Marine Sciences, Moss Landing Marine Laboratories, San Jose State University.
1986 Bachelor of Science, Conservation of Natural Resources, University of California, Berkeley.

Research Interests
Population, **C**ommunity, and restoration ecology.

Grants, Fellowships, and Honors
NSF- **Long-term Ecological Research: Moorea Coral Reef Ecosystem**. (Associate Investigator). 2004-2010. $4.8 million.
US MMS- **Ecological performance of and trophic links between POCS oil platforms and natural reefs.** (Co-P.I.). 2002-2005. $156,515.
US MMS- **Relative importance of POCS oil platforms to regional fish population dynamics** (Co-P.I.). 2002-2004. $112,348.
NSF- **Effects of multiple chemical stressors on Antarctic marine benthic communities** (Post-doc; Grant Author). 1997-2000. $435,000.
NRC- Postdoctoral Associate Program- **Identification and restoration of essential estuarine fishery habitat**. 1996-97. $34,000.
Sea Grant- **Monitoring and modeling the hydrography and fishery resources of an endangered river**. (co-P.I.). 1997-1998**.** $255,000
State of NC- **Experimental approaches to shellfishery management.** (P.I.). 1997. $29,500.
State of NC**- Fish community ecology of natural and restored estuarine habitats** (P.I.). 1996-1997.
NOAA- **Effects of multiple environmental stressors on parasitism within oysters** (Co-P.I.). 1995. $73,000.

Publications
Peterson, C.H., H.S. Lenihan, and S. Powers. *In press*. Ecological impacts of beach renourishment in offshore benthic communities. **Journal of Coastal Research**.
Sancho, G., C.R. Fisher, S. Mills, F. Micheli, G.A. Johnson, H.S. Lenihan, C.H. Peterson, and L.S. Mullineuax. *In press*. Selective predation by the zoarcid fish *Thermarces cerberus* at hydrothermal vents. **Deep Sea Research**.
Lenihan, H.S. and C.H. Peterson. 2004. Conserving oyster reef habitat by switching from dredging and tonging to diver hand-harvesting. **Fishery Bulletin** 165: 1-15.
Conlan, K.E., S.L. Kim, H.S. Lenihan, and J.S. Oliver. 2004. Benthic changes during 10 years of organic enrichment by McMurdo Station, Antarctica. **Marine Pollution Bulletin** 49: 43-60.
Lenihan, H.S., C.H. Peterson, S.L. Kim, K.E. Conlan, R. Fairey, C. McDonald, J.H. Grabowski, and J.S. Oliver. 2003. How variation in marine benthic community composition allows discrimination of multiple stressors. **Marine Ecology Progress Series** 206: 111-121
Conlan, K.E., S. L. Kim, H. S. Lenihan, and J. S. Oliver. 2003. Benthic community changes at

McMurdo Station, a response to sewage abatement? *In* A. H. L. Huiskes, W. W. C. Gieskes, J. Rozema, R. M. L. Schorno, S. M. van der Vies and W. J. Wolff (editors) **Antarctic biology in a global context**. Leiden, The Netherlands: Backhuys Publishers.

Micheli, F., C.H. Peterson, L.S. Mullineaux, C.R. Fisher, S.W. Mills, G. Sancho, G.A. Johnson, and H.S. Lenihan. 2002. Species interactions at deep-sea hydrothermal vents: the role of predation in structuring communities in an extreme environment. **Ecological Monographs** 73: 365-382.

Peterson, C.H., J.B.C. Jackson, M.X. Kirby, H.S. Lenihan, R. Borque, R. Bradbury, R. Cooke, and S. Kidwell. 2001. Factors in the decline of coastal ecosystems- Response. **Science** 293: 1590-1591.

Lenihan, H.S., C.H. Peterson, J.E. Byers, J.H. Grabowski, G.W. Thayer, and D.R. Colby. 2001. Cascading of habitat degradation: oyster reefs invaded by refugee fishes escaping stress. **Ecological Applications** 11: 748-764.

Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R. Bradbury, R. Cooke, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, and R. Warner. 2001. Historical overfishing and the collapse of marine ecosystems. **Science** 293: 629-638.

Lenihan, H.S. and F. Micheli. 2001. Soft sediment communities. *In* M. Bertness, M.E. Hay, and S.D. Gaines (editors), **Marine Community Ecology**. Sinauer Associates, Inc.

Peterson, C.H., H.C. Summerson, E. Thompson, H.S. Lenihan, J.H. Grabowski, L. Manning, F. Micheli, and G. Johnson. 2000. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. **Bulletin of Marine Scienc***e* 66: 759-774.

Lenihan, H.S., and F. Micheli. 2000. Biological effects of shellfish harvesting on oyster reefs: resolving a fishery conflict using ecological experimentation. **Fishery Bulletin** 98: 86-95.

Lenihan, H.S. 1999. Physical-biological coupling on oyster reefs: how habitat form influences individual performance. **Ecological Monographs** 69: 251-275.

Lenihan, H.S., F. Micheli, S.W. Shelton, and C.H. Peterson. 1999. How multiple environmental stresses influence parasitic infection of oysters. **Limnology and Oceanography** 44: 910-924.

Lenihan, H.S. and C.H. Peterson. 1998. How habitat degradation through fishery disturbance enhances effects of hypoxia on oyster reefs. **Ecological Applications** 8: 128-140.

Conlan, K.E., H.S. Lenihan, R.G. Kvitek, and J.S. Oliver. 1998. Iceberg scour disturbance to benthic communities in the Canadian High Arctic. **Marine Ecology Progress Series**. 160: 1-16.

Lenihan, H.S., C.H. Peterson, and J.M. Allen. 1995. Does flow also have a direct effect on growth of active suspension feeders: an experimental test with oysters. **Limnology and Oceanography** 41: 1359-1366.

Lenihan, H.S., K.A. Kiest, K.E. Conlan, P.N. Slattery, B.H. Konar, and J.S. Oliver. 1995. Patterns of survival and behavior of marine invertebrates exposed to contaminated sediments from McMurdo Station, Antarctica. **Journal of Experimental Marine Biology and Ecology** 192: 233-255.

Lenihan, H.S. and J.S. Oliver. 1995. Natural and anthropogenic disturbances to marine benthic communities in Antarctica. **Ecological Applications** 5: 311-326.

Lenihan, H.S. 1992. Benthic marine pollution around McMurdo Station, Antarctica: a summary of findings. **Marine Pollution Bulletin** 25: 318-323.

Lenihan, H.S., J.S. Oliver, J.M. Oakden, and M. Stephenson. 1990a. Intense and localized benthic marine pollution around McMurdo Station, Antarctica. **Marine Pollution Bulletin** 21: 422-430.

Lenihan, H.S., J.S. Oliver, and M. Stephenson. 1990b. Changes in hard-bottom communities related to boat-mooring and Tributyltin (TBT) in San Diego Bay: a natural experiment. **Marine Ecology Progress Series** 60: 147-159.

Kevin Faulkenberry, Senior Engineer (Registered) in California Department of Water Resources (CDWR), San Joaquin District. Mr. Faulkenberry received a BS in Civil Engineering and Geomatics Engineering from CSU Fresno in 1989. Currently he manages the San Joaquin District's River Management Section and the District's restoration program. While working to manage this program, Mr. Faulkenberry has developed many cooperative relations with local, State and federal agencies that have proven to be instrumental in all phases of project development and implementation. Mr. Faulkenberry has over ten years of experience in planning, permitting, surveying, designing, monitoring, maintaining and constructing river restoration projects on the San Joaquin River system while working for CDWR. Recent Projects include the Merced River Salmon Habitat Enhancement Project (MRSHEP), Calaveras River fish passage evaluation, Caltrans Fish Passage evaluation, San Clemente Dam Removal Evaluation, Jensen Ranch Restoration Project on the San Joaquin River, Milburn/Hansen Unit Restoration Project on the San Joaquin River, and is a technical reviewer for the Development of the Draft Restoration Strategies for the San Joaquin River. Other continuing and ongoing projects include monitoring of the MRSHEP, as well as gravel augmentation on the Tuolumne River at La Grange, on the Merced River at the Merced River Hatchery, and diversions.

Curriculum Vitae

CARL JOSEPH LEGLEITER

carl@geog.ucsb.edu

ADDRESS

Geography Department
Ellison Hall 3611
University of California Santa Barbara
Santa Barbara, CA 93106
(805) 893-4434

712 Bolton Walk
Apartment #203
Goleta, CA 93117
(805) 971-5924

EDUCATION

University of California Santa Barbara, Santa Barbara, CA (September, 2002 – Present)

- Pursuing Doctorate in Geography
- American Society for Engineering Education National Defense Science and Engineering Graduate Fellow (Awarded March, 2002)
- National Science Foundation Graduate Research Fellow (Awarded March, 2002)
- UCSB Regents Special Fellow (Awarded March, 2002)

Montana State University, Bozeman, MT (August, 1997 – May, 2002)

- B.S. in Earth Sciences, Geohydrology Option
- B.S. in Mathematical Sciences, Statistics Option
- University Honors Program Baccalaureate with Highest Distinction
- Cumulative 4.0 Grade Point Average
- Barry M. Goldwater Scholar (2000-2002)
- Senior Honors Thesis: *Fluvial response a decade after wildfire in the northern Yellowstone ecosystem: a spatially explicit analysis*
- Earth Sciences Department Senior Thesis: *Hyperspectral stream classification*

EXPERIENCE

Research Associate with Yellowstone Ecological Research Center (October, 2003 – Present)

- *Scientific advisor for river research*

  Development and application of techniques for retrieving geomorphic and ecological parameters from remotely sensed data; geostatistical analysis of field data and hyperspectral, microwave, and LIDAR imagery; prepare project reports and future funding proposals

California Space Institute Research Grant: *Remote Mapping and Geostatistical Analysis of Channel Morphology* (February – August, 2003)

- *Graduate research activity*

  Designed and implemented field data collection in support of remote sensing missions in Yellowstone National Park; performed *in situ* spectral measurements of channel and floodplain features; performed topographic survey of Soda Butte Creek; characterized sediment grain size distributions and surface roughness characteristics; developed sampling protocols and coordinated field activities; completed processing and analysis of spectral, survey, and geomorphic field data

EPA Grant: ***Developing Effective Ecological Indicators for Watershed Analysis*** **(September, 2001 – September, 2002)**

- *Research Assistant with Dr. Rick L. Lawrence*

  Spatial statistical analysis of fluvial geomorphic field data and watershed characteristics of eight streams in the upper Yellowstone River basin; gained proficiency with S-Plus software; developed spatially explicit generalized least squares regression models; conceptualized and articulated process-response models describing geomorphic effects of wildfire in the northern Yellowstone ecosystem; project served as senior Honors thesis; article published in *Geomorphology*

NSF Research Experiences for Undergraduates Program in Water Research at Colorado State University: ***Hydraulic and Structural Controls on Channel Morphology of the North Fork of the Cache La Poudre River*** **(June – July, 2001)**

- *Collaborative Research Activity (advised by Dr. Ellen E. Wohl)*

  Investigated interaction between hydraulic driving and substrate resisting forces as determinants of channel morphology; performed longitudinal survey and detailed geomorphic mapping using a total station and GPS; compiled final map with Pathfinder Office and ArcView software; acquired high-resolution digital photographs and developed Avenue script to calculate bedrock fracture density; multivariate statistical analysis conducted in S-Plus and Minitab; co-authored article published in *Journal of Geology*

Undergraduate Scholars Program Grant: ***Hyperspectral Stream Classification*** **(September, 2000 – May, 2001)**

- *Independent Research Activity (advised by Dr. W. Andrew Marcus)*

  Assessment of hyperspectral remote sensing as a tool for mapping stream morphology; evaluated supervised and unsupervised approaches to classification and performed multivariate statistical analyses; results presented at the 2001 Annual Meeting of the Association of American Geographers, earning the Water Resources Specialty Group Student Paper Award; project served as a departmental senior thesis and has been published in *Environmental Management*

EPA Grant: ***Developing Effective Ecological Indicators for Watershed Analysis*** **(July, 2000 – May, 2001)**

- *Research Assistant with Dr. W. Andrew Marcus*

  Field investigation of Yellowstone River Basin streams; detailed longitudinal surveys spanning a total of 85 km; channel characteristics, woody debris, and valley attributes inventoried at 100 m intervals; collection of hydraulic field data in coordination with AVIRIS flyover; preparation of drainage network maps from DEMs using Arc/Info and Imagine software; planning and logistical coordination of field activities

Montanans on a New Track for Science Undergraduate Research Program Grant (January – May, 2000)

- *Independent Research Activity (advised by Dr. W. Andrew Marcus)*

Accelerated coverage of remote sensing theory and image processing techniques; completion of ENVI software tutorial and refinement of skills using Probe-1 hyperspectral data from 1999 NASA EOCAP; imported field maps of stream morphologic units, rectified imagery, transformed image data, performed supervised and unsupervised classifications

NASA EOCAP: *Validation of High-Resolution Hyperspectral Data for Stream and Riparian Habitat Analysis* (August, 1999 – June, 2000)

- *Research Assistant with Dr. W. Andrew Marcus*

  Fieldwork conducted on Yellowstone National Park streams; mapped over 15 km of stream morphologic units to hyperspectral imagery, collected sediment samples analyzed for heavy metals, studied riparian vegetation, and provided backcountry support; data management and analysis using ArcView GIS; only undergraduate involved in the project

Montana Water Center (January – July, 1999)

- *Student intern working in cooperation with the Montana Department of Environmental Quality (DEQ)*

  Database development and web page design for the Water Center; improved statewide Expertise Database and enabled online search capabilities; utilized Tango software to create an Internet Data Acquisition System for the DEQ that is used by Montana industries to report atmospheric pollution parameters in compliance with EPA standards

ARTICLES, REPORTS, AND PRESENTATIONS

- Legleiter, C.J., and Roberts, D.A., In preparation. Remote mapping of river channel morphology: physical basis and feasibility.
- Legleiter, C.J., and Goodchild, M.F., In review. Alternative representations of in-stream habitat. Submitted to International Journal of Geographic Information Science.
- Legleiter, C.J., 2003. Spectrally driven classification of high spatial resolution, hyperspectral imagery: A tool for mapping in-stream habitat. Environmental Management, 32(3) 399-411.
- Marcus, W.A., Legleiter, C.J., Aspinall, R.J., Boardman, J.W. and Crabtree, R.L., 2003. High spatial resolution hyperspectral mapping of in-stream habitats, depths, and woody debris in mountain streams. Geomorphology, 55(1-4): 363-380.
- Legleiter, C.J., Lawrence, R.L., Marcus, W.A., Fonstad, M.A., and Aspinall, R., 2003. Fluvial response a decade after wildfire in the northern Yellowstone ecosystem: A spatially explicit analysis. Geomorphology, 54(3-4): 119-136.
- Wohl, E.E., and Legleiter, C.J., 2003. Controls on pool characteristics along a resistant boundary channel. Journal of Geology, 111(1): 103-114.
- Legleiter, C.J., Marcus, W.A., and Lawrence, R.L., 2002. Effects of sensor resolution on mapping in-stream habitats. Photogrammetric Engineering & Remote Sensing, 68(8): 801-807.

How Abiotic Processes, Biotic Processes, and Their Interactions Sustain Habitat Characteristics and Functions in River Channels and their Floodplains: An Investigation of the Response of a Gravel-Bed Reach of the Merced River to Restoration: Signature

This proposal is for the Science Program 2004 solicitation as prepared by Dunne, Thomas.

[redacted]

The applicant for this proposal must submit this form by printing it, signing below, and faxing it to +1 877-408-9310.

Failure to sign and submit this form will result in the application not being considered for funding. The individual submitting this proposal will receive e-mail confirmation as soon as this signature page has been processed.

The individual signing below declares that:

- all representations in this proposal are truthful;
- the individual signing the form is authorized to submit the application on behalf of the applicant (if applicant is an entity or organization);
- the applicant has read and understood the conflict of interest and confidentiality discussion under the Confidentiality and Conflict of Interest Section in the main body of the PSP and waives any and all rights to privacy and confidentiality1 of the proposal on behalf of the applicant, to the extent provided in this PSP; and
- the applicant has read and understood all attachments of this PSP.

Proposal Title: How Abiotic Processes, Biotic Processes, and Their Interactions Sustain Habitat Characteristics and Functions in River Channels and their Floodplains: An Investigation of the Response of a Gravel-Bed Reach of the Merced River to Restoration

Proposal Number: 2004.01-0295

Submitter: Dunne, Thomas (tdunne@bren.ucsb.edu)

Thomas Dunne 1/6/05

applicant signature Karen T. Hanson **date** 1/6/05

Thomas Dunne, PI Karen Hanson, Associate Director of Sponsored Projects University of California, Santa Barbara

printed name of applicant **applicant organization**